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Stennis Space Center, MS 39529-5004

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Software Design Document for the Navy Standard Surf Model Version 3.2

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14. ABSTRACT

This Software Design Document (SDD) is written for the updated Navy Standard Surf Model, Version 3.2, or SURF 3.2, submitted to the Oceanographic and Atmospheric Master Library (OAML). The new model includes improved wave refraction, modified surf index, and beach slope computations, and many other refinements such as reduced user input. An overview of the surf model and scientific equations for wave and longshore current computations are included. The SDD provides descriptions of software design and code. Detailed explanations of input parameters and model options are included.

15. SUBJECT TERMS

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SOFTWARE DESIGN DOCUMENT FOR THE NAVY STANDARD SURF MODEL VERSION 3.2

1.0 SCOPE

1.1 Identification

This Software Design Document (SDD) is written for the Navy Standard Surf Model, version 3.2, or SURF 3.2. SURF 3.2 will be called SURF hereafter. SURF provides users with an automated method for determining surf conditions and related environmental parameters. The model produces a standard surf forecast such as breaker height, longshore current, and a modified surf index (MSI) number, which are Navy requirements for littoral operations and amphibious landings (see Joint Surf Manual). The first operational Navy surf forecasting computer model was developed for the Fleet in 1988 (Earle, 1988) to supplement the manual and visual techniques developed in the 1950's. The manual procedures are subjective and do not adequately consider shallow water effects such as wave shoaling and refraction. SURF is a modern numerical model and has been validated by field and laboratory data (Hsu et al. 2000 and 2002).

1.2 Document Overview

This OAML SDD describes the design, structure, and scientific aspects of the Computer Software Configuration Item (CSCI) titled SURF. This document provides a detailed summary of all Computer Software Units (CSU) or subroutines, input file formats, output file formats, and user-specified options. The SDD is divided into three sections: the Preliminary Design, the Architectural Design, and the Detailed Design.

The Preliminary Design section describes the scientific aspects of SURF including a brief description of the mathematical formulation and theory behind the model. The Architectural Design section outlines the structural design of SURF with a graphical representation of the CSU calling sequence. The Detailed Design section identifies and summarizes the operation of each CSU including detailed listings of input variables, output variables, local variables, calling routines, and called routines and/or called functions.

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3.0 PRELIMINARY DESIGN

3.1 CSCI Overview

SURF is a parametric one-dimensional model based largely on the work of Thornton and Guza (1983, 1986). Thornton and Guza developed several models for random wave processes including a wave height transformation model and a longshore current model. These models contain both numerical and analytical solutions, which provide cross-shore distributions of various parameters such as wave height, longshore current velocity, and wavelength. However, because SURF is one-dimensional, certain approximations are made: (1) straight and parallel bottom contours, (2) depth-uniform currents, (3) wave heights are Rayleigh distributed, (4) linear wave theory is applicable, and (5) directional wave spectra are narrow-banded in frequency and direction.

The model is designed to operate in a variety of modes to provide both military and civilian users with local surf and current forecasts. SURF requires three pieces of information to perform calculations: (1) a depth profile, (2) a directional wave spectrum, and (3) wave refraction information. Each of these required data sources can be accessed externally or generated internally. This design allows for maximum flexibility when using SURF to generate local forecasts where input data may or may not be available. The following subsections outline the scientific principles behind SURF and the inherent fundamental hydrodynamic calculations contained in the model.

3.1.1 Wave and Roller Energy Models

As waves approach the coast, the frictional effect of the sea floor on the organized orbital motion of water particles within a wave causes the wave to break or spill. The flows of spilling breakers can be separated into two layers, an upper layer of turbulent energy, which rides over a lower layer of energy that maintains an organized oscillatory wave motion. The region of turbulent water above the wave is termed a surface roller. The original idea of such a two-layer system was introduced by Longuet-Higgins and Turner (1974) (see also Svendsen (1984 a,b)). SURF incorporates the model of Lippman *et al* (1995, 1996), which produces results consistent with measurements from both a planar and a barred beach. The energy associated with each region of interest is utilized to shoal the incoming waves and drive the longshore current. The energy per unit surface area in a wave is calculated as:

$$E_w = \frac{1}{8}\rho g H_{rms}^2$$

where ρ is water density and g is the acceleration due to gravity. H_{rms} is the root-mean-square wave height. The energy per unit area associated with a roller is given as:

$$E_r = \frac{1}{8}\rho c f \frac{H_b^3}{h \tan\sigma}$$

where c is the phase speed of the wave, f is the zero crossing frequency, H_b is the height of the wave at breaking, h is water depth, and σ is the angle the roller makes with the body of the wave. A

default value of 5 degrees is used for the roller angle.

3.1.2 Energy Dissipation in the Surf Zone

As a wave propagates across the surf zone, its energy is dissipated due to bottom friction, wave breaking, turbulence, and wave-current interaction. A formulation of this energy dissipation is given by the energy flux equation:

$$\frac{\partial(E_w c_g \cos\theta)}{\partial x} = -<\varepsilon_b>$$

where E_w is the wave energy, c_g is the wave group velocity and θ is the wave direction relative to shore normal (*x* positive offshore). The Right Hand Side (RHS) of the above, equation, $<\varepsilon_b>$, is the ensemble averaged dissipation function. Thornton and Guza (1983) modeled this dissipation function as:

$$<\varepsilon_b> = \frac{1}{4}\rho g f \frac{B^3}{h}\int H^3 p_b(H)dH$$

where *B* is an empirical coefficient, and $p_b(H)$ is the probability distribution for breaking waves described by:

$$p_b(H) = W(H)p(H)$$

where *p(H)* is a Rayleigh Distribution of wave heights and *W(H)* is a weighting function resulting in a weighted Rayleigh distribution. Several weighting functions *W(H)* have been constructed by various authors, the weighting function applied in SURF developed by Thornton and Guza (1986) is given as:

$$W(H) = \left[\frac{H_{rms}}{\gamma h}\right]^4 \left(1 - e^{-\left[\frac{H}{\gamma h}\right]^2}\right)$$

where γ is an empirical factor determined from field data to be 0.42, *h* is the water depth and *H* is the wave height. If wave roller energy is considered in the model, the modified energy flux equation is given as:

$$\frac{\partial(E_w c_g \cos\theta)}{\partial x} + \frac{\partial(E_r c \cos\theta)}{\partial x} = -<\varepsilon_r>$$

and the dissipation becomes a function of the roller term.

$$<\varepsilon_r> = \frac{1}{4}\rho g f \frac{H_b^3}{h}\cos\sigma \int H^3 p_b(H)dH$$

The above equation is solved using a numerical forward stepping and convergence scheme to determine wave and roller energy along with H_{rms} values at each point.

3.1.3 Longshore Current Calculations

When waves enter the surf zone at an angle, the shore-parallel component of momentum inherent to wave motion drives a current along the shore. This longshore current can be a significant force inside the surf zone. Calculation of the current velocity is based on radiation stress theory (see Longuet-Higgins, 1970a, 1970b). A general form of the longshore momentum equation is:

$$\tau_y^h + \rho\frac{d}{dx}\left(\mu h\frac{dV}{dx}\right) - <\tau_y^b> + \tau_y^w = 0$$

where ρ is the water density, h is the water depth, and V is the longshore current. The first term on the left hand side is the radiation stress in the along shore direction exerted by waves on the water given by:

$$\tau_y^h = <\varepsilon_b>\frac{\sin\theta}{c}$$

where ε_b is the dissipation function defined in the previous section, c is wave phase speed, and θ is the angle of wave approach with respect to x. The second term is the horizontal mixing. The horizontal eddy viscosity μ is modeled after Battjes (1975).

$$\mu = Mh\left(\frac{\varepsilon_b}{\rho}\right)^{\frac{1}{3}}$$

in which M is an empirical constant equal to 2. The third term is the mean stress due to bottom friction given by:

$$\tau_y^b = \rho\, c_f\, uV$$

where c_f is the bottom friction coefficient, u is the magnitude of the near-bottom horizontal wave orbital velocity, and V is the longshore current. Linear wave theory defines the near-bottom wave-induced orbital velocity as:

$$u = \frac{\pi H}{T\sinh(kh)}$$

where H is the wave height, T is the wave period and k is the wave number, which can be calculated using the dispersion relation:

$$\sigma^2 = g\,k\tanh(k\,h)$$

where σ is the radian wave frequency and g is gravity. The longshore current equation is solved using a finite difference approach after wave heights, water depths, and wave dissipation values are calculated at each cross-shore grid point in the surf zone.

A major improvement to the longshore current calculation is included in SURF. Hsu et al. (2000) showed that using a variable bottom friction coefficient formulation in the longshore current model provides a significant improvement in longshore current velocities. The depth dependent bottom friction coefficient function is defined as

$$c_f(x) = \begin{cases} 0.0035 & ;\ x \ge \dfrac{X_b}{2} \\[2ex] 0.0035\left(\dfrac{h\dfrac{X_b}{2}}{h(x)}\right) & ;\ x < \dfrac{X_b}{2} \end{cases}$$

where x is the offshore distance, h is the local water depth, and X_b is the distance from the shoreline to the location where ten percent of the waves are breaking.

3.1.4 Directional Energy Spectra

SURF allows users to generate surf forecasts using two different directional wave energy spectrum types. The user can choose from an internally generated wave spectrum or an external wave spectrum. If the internally generated spectrum is selected, a modified Pierson-Moskowitz (1964) spectrum is calculated based on sea and swell conditions defined in the surf model input file.

3.1.5 Differences Between SURF 3.1 and SURF 3.2

There are many code improvements in SURF 3.2. In general, the prolog of each routine in the software was changed to reflect individual changes and in many routines, comments were added, clarified, deleted or corrected, where necessary. The major changes in the software are as follows:

1. The lookup table in routine MDSRF2 was corrected to the values in the Joint Surf Manual. There had been seven typographical errors, which produced inconsequential errors in the modified surf index. In the process of correcting these errors, the routine was streamlined and documented better than it had been.

2. At the request of Systems Integration Division, Naval Oceanographic Office, the input variable dstart, i.e. the starting depth of the surf computation, was eliminated from the SURF input file. This variable is now automatically calculated in the model from information in the depth profile, the depth of the input waves and the refraction option. The order of input parameters

was re-arranged for clarity.

3. The output file of SURF had traditionally produced a profile, or listing, of wavelength through the surf zone but never a listing of wave direction; although, directional variation throughout the surf zone is more operationally relevant than variation in wavelength. Therefore, in the detailed output, wavelength has been replaced by wave direction. This change required adding another routine (lin4) and making minor changes to several other routines. Extra lines were added in the summary part to list the average wavelength and the depth of wave input.

4. The routines related to equilibrium profile, starting point, percent of breaking and wave refraction option were improved.

5. Several variables, constants and arrays, which are passed through several unnecessary levels of computation, were either eliminated or appropriately moved.

6. Superfluous routines associated with experimental versions of SURF were eliminated. These routines allowed an alternative, but unnecessarily complex, calculation of longshore current. Routines b_head and b_detail were merged into the summary routine.

7. The angle used for initializing the wave transformation through the surf zone was replaced from the direction of the vertically averaged momentum flux to the energy-weighted, mean wave direction. The change was made because, by definition, the former angle limits wave directions to within 45 degrees of shore normal, which was found to be an unrealistic constraint. In changing the definition of the initializing wave angle, it was necessary to increase the bottom friction coefficient from 0.0030 to 0.0035 after re-calibrating the model using field data.

8. The cross-shore distance over which bottom slope is calculated for subsequent estimates of breaker type was increased from approximately 6 feet to a one-quarter the wavelength. The maximum distance is limited to 100 ft and the minimum distance is set to 10 ft. A routine (get_slope) was added for this calculation. This change has effectively reduced the unusually high incidence of estimates of surging breakers.

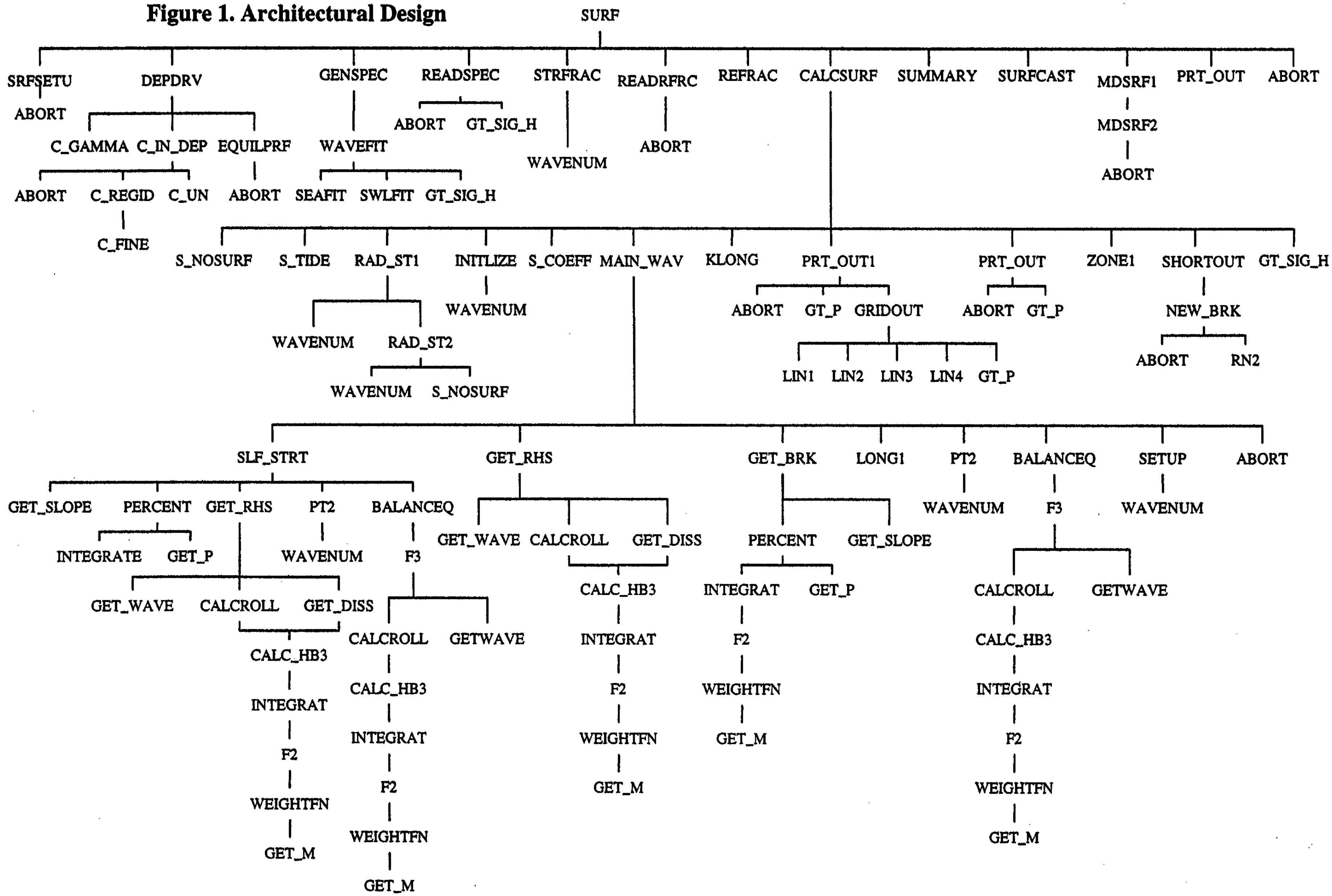
9. The interpolation scheme in the routine grd_frc was completely re-written to reflect a bilinear interpolation scheme, which is simpler and more efficient than what had been in place.

10. The routine refrac was improved to proportionally distribute refracted wave energy into adjacent directional bins. Earlier versions of this routine refracted energy into one bin only and thus produced and unrealistic step-like patterns in directional wave spectra.

4.0 ARCHITECTURAL DESIGN

The Architectural Design section shows the overall design and the calling sequence for all CSUs of the SURF. Each CSU is shown in the calling sequence with the associated CSU related to each specific unit. Figure (1) presents the path in which each CSU is called and all associated CSUs, which in turn are called from the parent unit. Specific details concerning the criteria for each CSU being called are defined in the Section 5.0: SURF CSU Detailed Design.

Figure 1. Architectural Design



5.0 CSCI DETAILED DESIGN

5.1 Program SURF

Program Call:

SURF ( )

Summary:

The SURF routine is the starting point for executing SURF. The routine identifies the input type and controls the reading of data and user selected computation options. The routine calls the main wave parameter calculation routines and controls the output of the resulting data.

Input Variables: None.

Output Variables: None.

Local Variables:

alfa	Real	Significant Breaker Height
bravo	Real	Maximum Breaker Height
chrlie	Real	Dominant Breaker Period
dangle	Real	Angle Between Directional Bins
depname	Char*40	Depth Profile File Name
dsea	Real	Input Direction for Sea Contribution
dstart	Real	Input Starting Depth
dswell	Real	Input Swell Direction for Internally Generated Spectrum
dxy1 (points)	Real	Corresponding Depths with No Tide
echo	Real	Breaker Angle
ehsig	Real	Significant Wave Height from Directional Spectrum
esowm (dirNum,freqNum)	Real	Directional Wave Spectrum
file_dat	Char*40	Output File Name *.dat
file_in	Char*40	Input Filename
file_out	Char*40	Output File Name *.out
file_tmp	Char*40	Temporary File
foxtrt	Real	Longshore Current Speed and Direction
fracname	Char*40	Wave Refraction File Name
freq (freqNum)	Real	Input Wave Spectrum Center Frequencies
freq1 (freqNum)	Real	Beginning Frequency Bin Values
freq2 (freqNum)	Real	Ending Frequency Bin Values

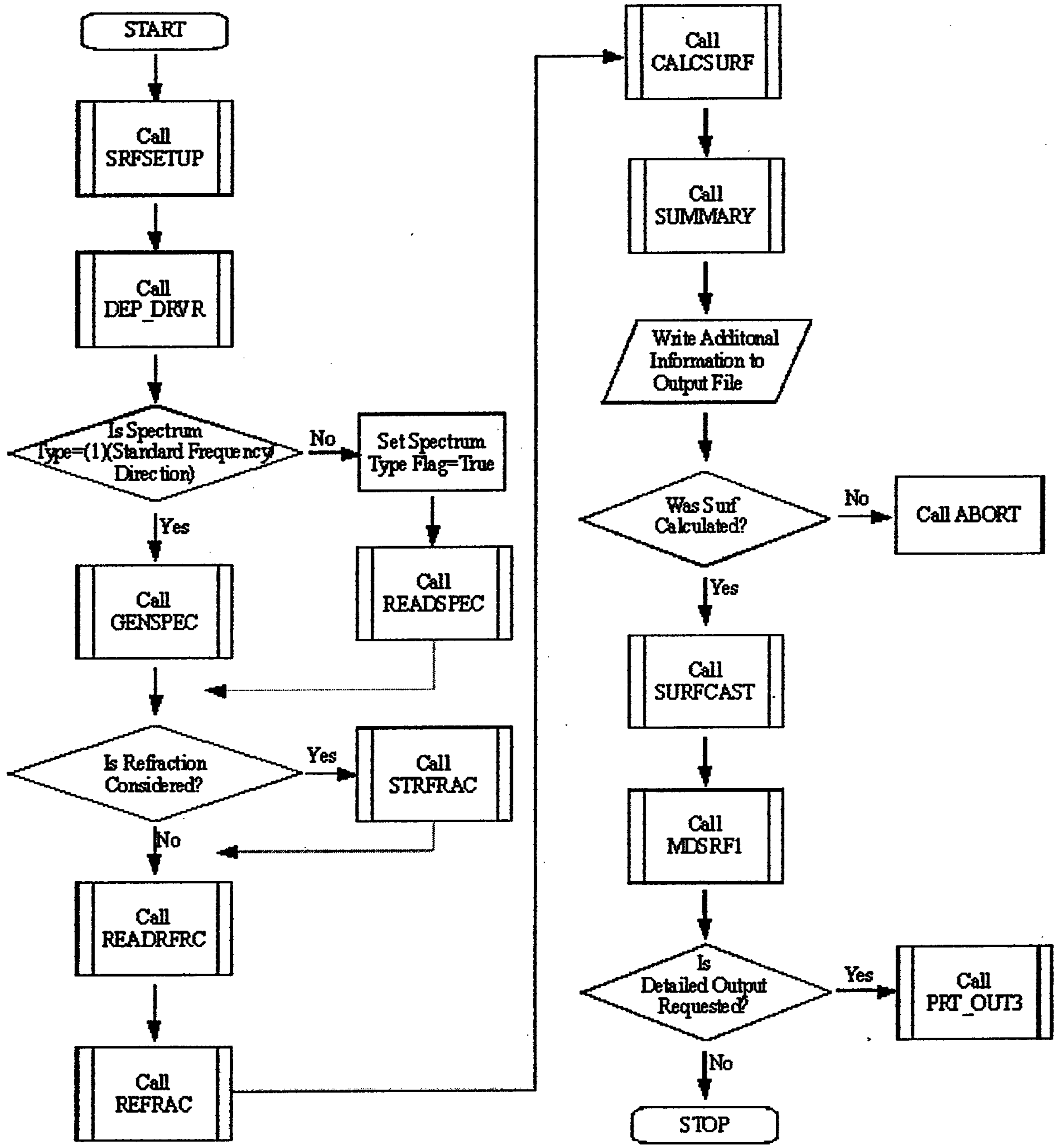
gamma2	Real	Beach Orientation, Compass Heading Directly Toward Beach
golf1	Real	Number of Surf Lines
golf2	Real	Surf Zone Width
gt_frq	Integer	Spectrum Type
hsea	Real	Input Significant Wave Height for Sea Contribution to Pierson Moskowitz Spectrum
hswell	Real	Input Significant Wave Height for Internally Generated Spectrum
iday	Integer	Input Day
idirec	Integer	Number of Direction Bins in the Input Spectrum
ifreq	Integer	Number of Frequency Bands in the Input Spectrum
igamma	Integer	Beach Orientation Rotated 90° from Original Heading Toward Beach
ihour	Integer	Input Hour
ihtl1	Real	Wind Speed Coded Surf Forecast Value
ihtl2	Real	Wind Direction
imin	Integer	Input Minute
imonth	Integer	Input Month
iyear	Integer	Input Year
jgamma	Integer	Temporary Value Set to Beach Orientation
line	Char*80	Temporary Character Variable
lin_stress	Logical	Longshore Current Solution (True or False)
lndname	Char*40	Input Landing Zone Name
nnn	Integer	Number of Points in the Input Depth Array
pct (4)	Real	Percent of Different Breaker Types pct (1) = Spilling pct (2) = Plunging pct (3) = Surging pct (4) = Total
period (freqNum)	Real	Period Array (1/Frequency)
psea	Real	Input Wave Period for Sea Contribution to Pierson Moskowitz Spectrum
pswell	Real	Input Swell Period for Internally Generated Spectrum
roller	Logical	Roller Usage (True or False)
self_st	Char*1	Self Start Flag (Yes or No)
slope	Real	Bottom Slope
spectra	Logical	Does Input Spectra Exist? (True or False)
spefile	Char*40	Selected Wave Spectrum File Name
surfy	Logical	Significant Wave Heights Greater than 0.5 ft? (True or False)
tide	Real	Input Tide Level

wdir	Real	Input Wind Direction Compass Heading Wind Blows from
wspd	Real	Input Wind Speed
xcoeff (dirNum, freqNum)	Real	Wave Height Refraction Coefficients
xdelt	Real	Surf Zone Output Interval
xdelt_gr	Real	Self Adjusting Cross-Shore Grid Step
xfrom (dirNum)	Real	Direction Array, Direction Wave Energy Comes From
xtheta (dirNum,freqNum)	Real	Angle Refraction Coefficients
xx1(points)	Real	Adjusted Cross-Shore Distances from Depth Profile
ydepth	Char*1	Input Depth Profile Used? (Yes or No)
ydetail	Char*1	Detailed Output? (Yes or No)
yrefrac	Char*1	Is Refraction Considered in Analysis? (Yes or No)
ystr	Char*1	Is Straight Coast Refraction Used? (Yes or No)

Subroutines Called from SURF ( ):

ABORT
CALCSURF
DEPDRVR
GENSPEC
MDSRF1
PRT_OUT3
READRFRC
READSPEC
REFRAC
SRFSETUP
STRFRAC
SUMMARY
SURFCAST

Figure 2. Program SURF Flowchart



5.2 Subroutine ABORT

Subroutine Call:

ABORT ( )

Summary:

Subroutine ABORT acts as the single program termination routine. The subroutine handles normal program execution and error interrupt. ABORT is called to stop the execution of the program. If an error interrupt calls ABORT, the error message is generated locally in the calling routine.

Input Variables: None.

Output Variables: None.

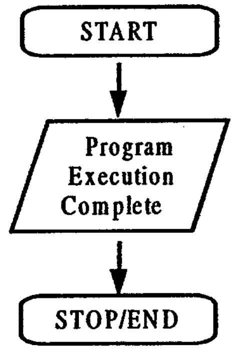
Local Variables: None.

Subroutines Called from ABORT ( ): None.

ABORT ( ) Called from Subroutines:

C_IN_DEP
EQUILPRFMAIN_WAV
MDSRF2
NEW_BRK
NONLIN2
PRT_OUT1
PRT_OUT2
READRFRC
READSPEC
SRFSETUP
SURF

Figure 3. Subroutine ABORT Flowchart



5.3 Subroutine BALANCEQ

Subroutine Call:

BALANCEQ (roller, theta, Cg, rhs, hrms1, dp, mean_freq, xk, hrms2, convg)

Summary:

Subroutine BALANCEQ computes new wave height value at the next onshore grid cell by performing an iterative solution to the energy equations.

Input Variables:

Cg	Real	Wave Group Velocity
dp	Real	Offshore Water Depth
hrms1	Real	Root Mean Square Wave Height
mean_frq	Real	Wave Frequency
rhs	Real	Right Hand Side of Energy Balance Equation
roller	Logical	Roller Option Flag (True or False)
theta	Real	Wave Angle
xk	Real	Wave Number

Output Variables:

convg	Logical	Convergence Flag (True or False)
hrms2	Real	Significant Wave Height at next Onshore Grid

Local Variables:

avgh	Real	Average Wave Height
check	Real	Convergence Check
done	Logical	Flag indicating End of Loop
f3	Real	Function which Calculates Total Energy
kount	Integer	Loop Iteration Counter
lhs	Real	Left Hand Side of the Energy Equation
limit	Logical	Flag for Comparison of the Left & Right Side of the Energy Equation (True or False)
lowerh	Real	Lower Limit of Wave Height
max_kount	Integer	Maximum Number of Loop Iterations =1000
oldavgh	Real	Previous Average Wave Height Value
pct	Real	Convergence Step Value
tol	Real	Convergence Tolerance
upperh	Real	Upper Limit of the Wave Height

Subroutines Called from BALANCEQ ( ): None

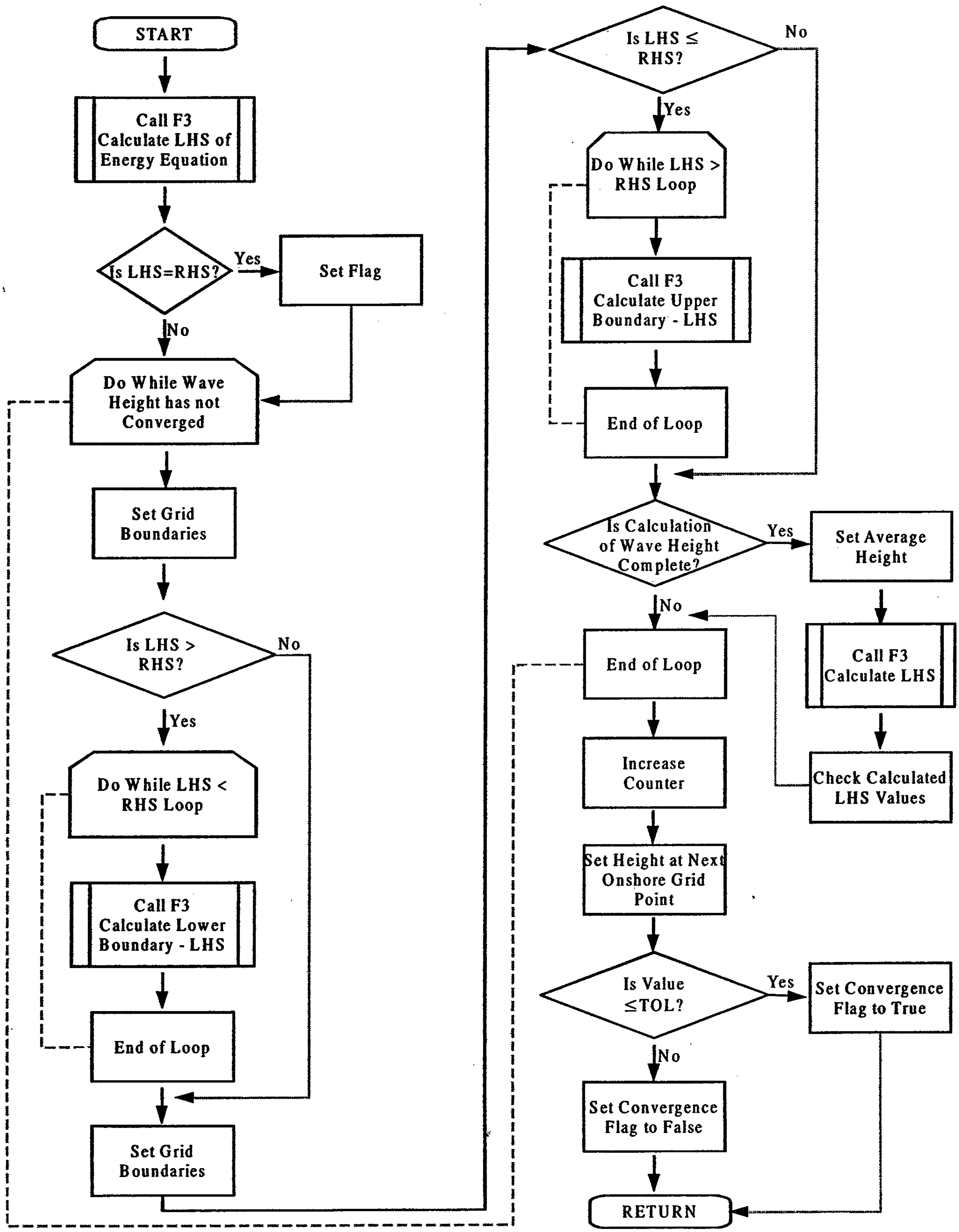
Functions Called from BALANCEQ ( ):

F3

BALANCEQ ( ) Called from Subroutines:

MAIN_WAV
SLF_STRT

Figure 4. Subroutine BALANCEQ Flowchart



5.4 Subroutine C_FINE

Subroutine Call:

C_FINE (ndepth, xxin, zzin, xdelt_gr, nnn, xx1, dxy1)

Summary:

Subroutine C_FINE linearly interpolates the input water depths and offshore distances to an evenly spaced grid. The internally defined grid self-adjusts to maximize spatial resolution without exceeding the array dimensions.

Input Variables:

ndepth	Integer	Number of Points in Input Depth Profile
xdelt_gr	Real	Self-Adjusting Cross-Shore Grid Step
xxin (points)	Real	Cross-Shore Distances
zzin (points)	Real	Corresponding Depths

Output Variables:

dxy1 (points)	Real	Corresponding Depths without Tide
nnn	Integer	Number of Points in the Input Depth Array
xx1 (points)	Real	Adjusted Cross-Shore Distances from Depth Profile

Local Variables:

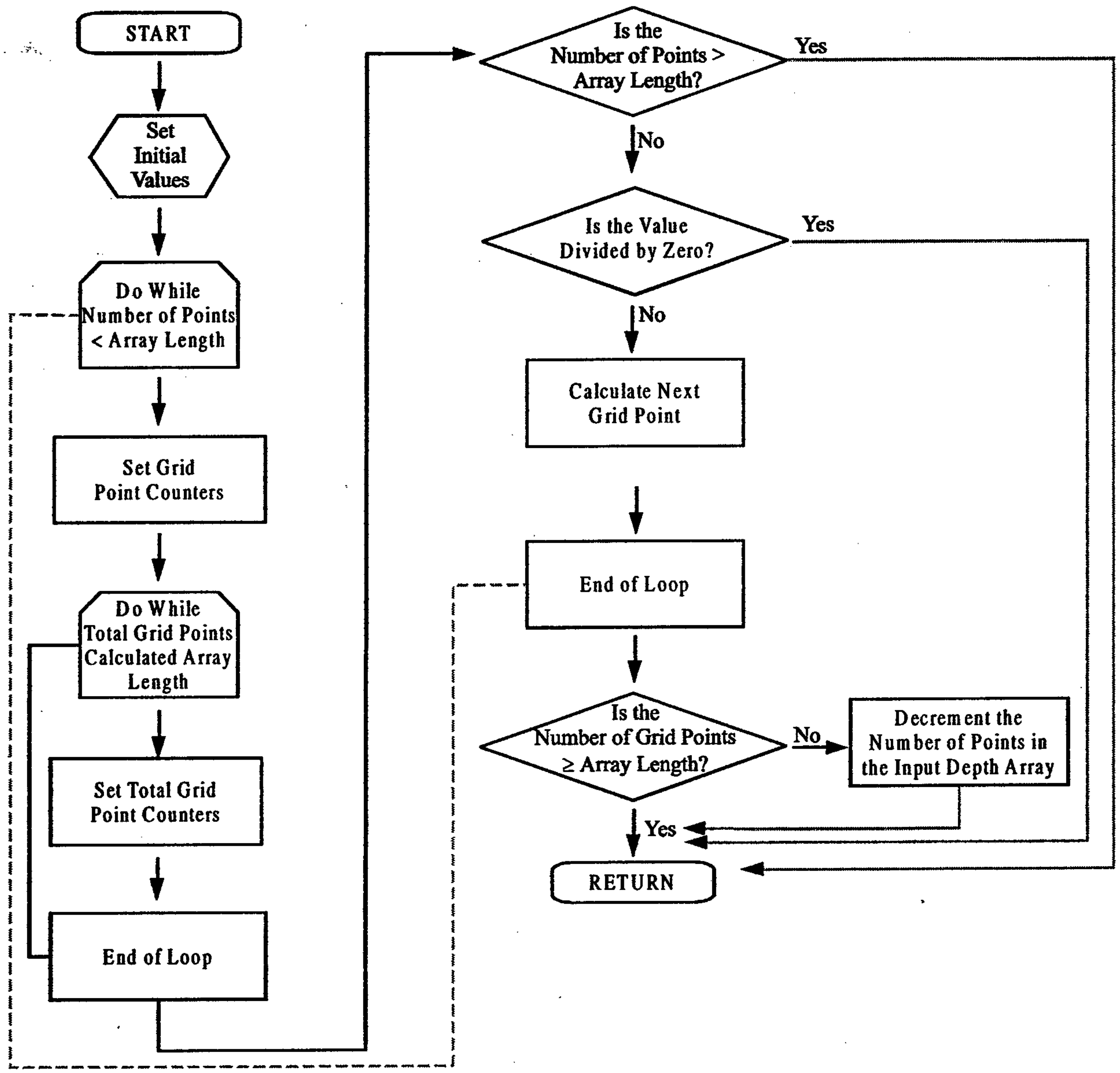
dx1	Real	Temporary Variable Used in Calculation of Next Grid Point Distance
dx2	Real	Temporary Variable Used in Calculation of Next Grid Point Distance
dxx	Real	Distance Quotient
dzz	Real	Difference Between Depth and Previous Depth
mm	Integer	Counter Variable
mm1	Integer	Counter Variable
mmm	Integer	Counter Variable
nn	Integer	Counter Variable
xlast	Real	Last Distance Offshore from Input Profile
xtemp	Real	Temporary Variable for Cross-Shore Values

Subroutines Called from C_FINE ( ): None.

C_FINE ( ) Called from Subroutines:

C_REGRID

Figure 5. Subroutine C_FINE Flowchart



5.5 Subroutine C_GAMMA

Subroutine Call:

C_GAMMA (gamma2, igamma)

Summary:

Subroutine C_GAMMA rotates the beach orientation data read from the input file. The user defines the beach orientation as the compass heading of a boat traveling directly toward the shore on a perpendicular line to the coast. The value is then rotated to reflect the orientation of the local coastline with respect to magnetic north.

Input Variables:

gamma2	Real	Beach Orientation, Heading Directly Toward Beach

Output Variables:

igamma	Integer	Rotated Beach Orientation

Local Variables:

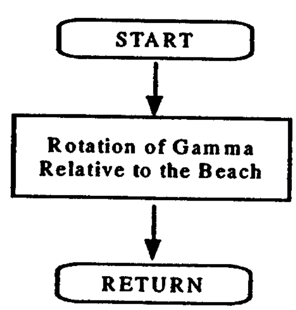
gammatp	Real	Temporary Variable Used in Calculation
mtemp	Integer	Temporary Variable in Calculation

Subroutines Called from C_GAMMA ( ): None.

C_GAMMA ( ) Called from Subroutines:

DEPDRVR

Figure 6. Subroutine C_GAMMA Flowchart



5.6 Subroutine C_IN_DEP

Subroutine Call:

C_IN_DEP (depname, spedepth, xdelt_gr, nnn, xx1, dxy1, dstart)

Summary:

Subroutine C_IN_DEP reads the depth profile and header information contained in the input data file. The routine identifies the units of measurement used to construct the depth profile and checks the order of the offshore distances. If the data is misaligned, the subroutine will sort and reorder the depths and offshore distances.

Input Variables:

depname	Char*40	Depth Profile File Name
dstart	Real	Input Starting Depth
xdelt_gr	Real	Self Adjusting Cross-Shore Grid Step

Output Variables:

dxy1 (points)	Real	Corresponding Depths without Tide
nnn	Integer	Number of Points in the Input Depth Array
xx1 (points)	Real	Adjusted Cross-Shore Distances from the Depth Profile

Local Variables:

a1	Real	Temporary Variable
a2	Real	Temporary Variable
adum	Char*80	Temporary Variable, Character String in Input Field
dcal1	Real	Conversion Factor for Distance Offshore, Convert to Meters
dcal2	Real	Conversion Factor for Depths Offshore, Convert to Meters
dx	Real	Temporary Variable for Distance Offshore from Input File
dz	Real	Temporary Variable for Depths
I	Integer	Loop Variables
icall	Integer	Input from Depth File, Units of Distance Offshore 1 = Feet

		2 = Meters
		3 = Yards
ical2	Integer	Depth Units Input from Depth File
		1 = Feet
		2 = Meters
		3 = Fathoms
instat	Integer	File Open Status
j	Integer	Loop Variables
k	Integer	Temporary Variable for Number of Points
line	Integer	Counter for the Number of Lines in the Input Depth Profile
loop	Integer	Loop Counter
ndepth	Integer	Number of Points in Input Depth Profile
xxin (points)	Real	Cross-Shore Distances
zzin (points)	Real	Corresponding Depths

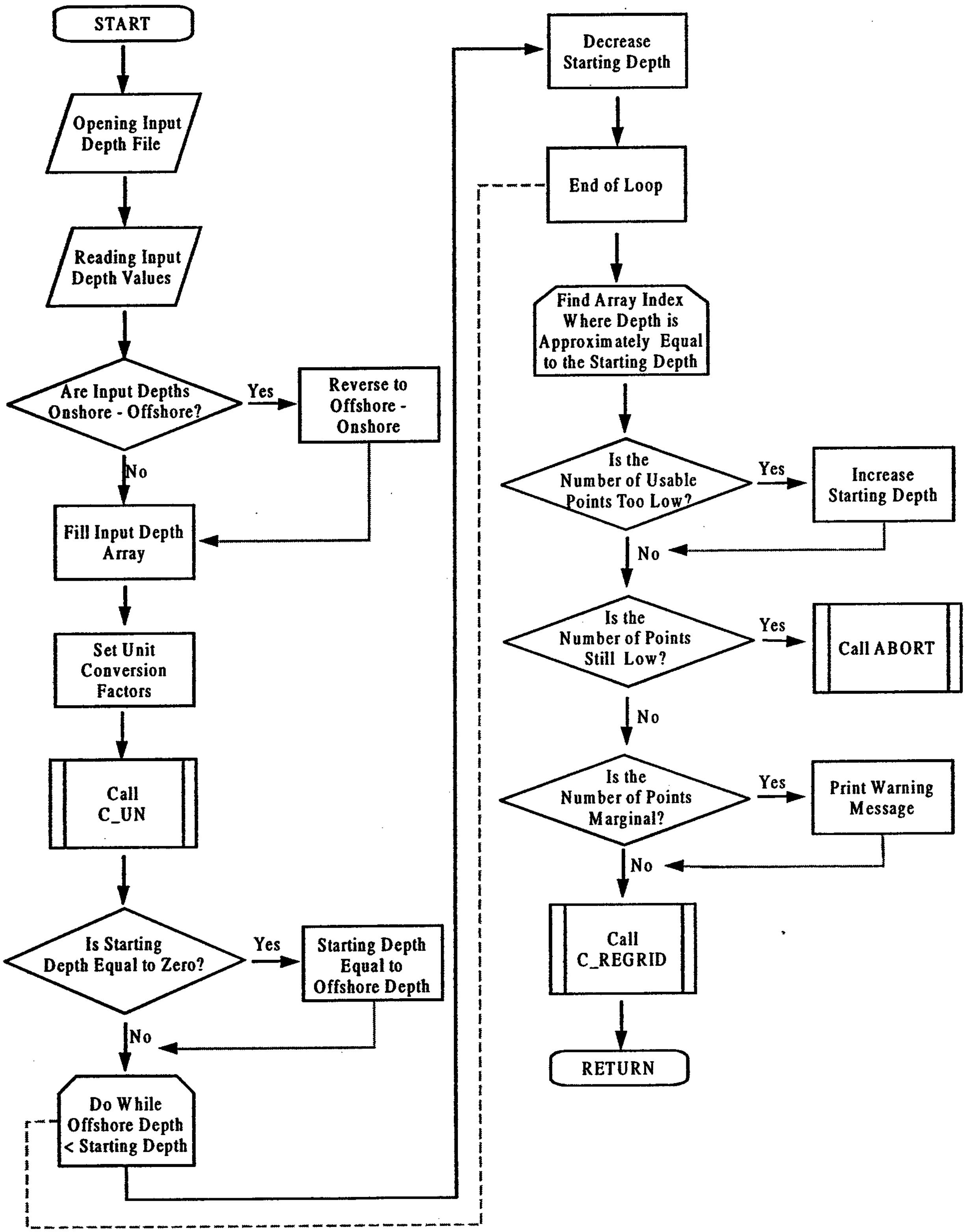
Subroutines Called from C_IN_DEP ( ):

ABORT
C_UN
C_REGRID

C_IN_DEP ( ) Called from Subroutines:

DEPDRVR

Figure 7. Subroutine C_IN_DEP Flowchart



5.7 Subroutine C_REGRID

Subroutine Call:

C_REGRID (ndepth, xxin, zzin, xdelt_gr, nnn, xx1, dxy1)

Summary:

Subroutine C_REGRID examines the cross-shore step size (Δx) of the input depth profile and selects a new step size to optimize the depth and cross-shore distance arrays. The step size is automatically adjusted and the arrays are constructed so the length does not exceed the dimension of the array.

Input Variables:

ndepth	Integer	Number of Points in Depth Profile
xdelt_gr	Real	Self Adjusting Cross-Shore Grid Step
xxin (points)	Real	Cross-Shore Distances
zzin (points)	Real	Corresponding Depths

Output Variables:

nnn	Integer	Number of Points in Input Depth Array
xdelt_gr	Real	Self Adjusting Cross-Shore Grid Step
xx1(points)	Real	Adjusted Cross-Shore Distances from Depth Profile
xxin (points)	Real	Adjusted Cross-Shore Distances
zzin (points)	Real	Corresponding Depths

Local Variables: None.

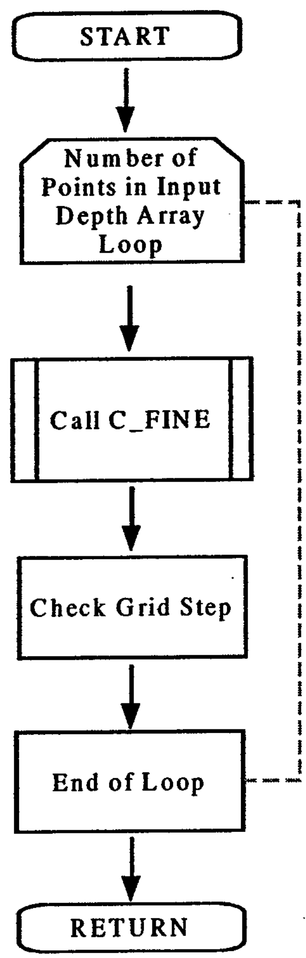
Subroutines Called from C_REGRID ( ):

C_FINE

C_REGRID ( ) Called from Subroutines:

C_IN_DEP

Figure 8. Subroutine C_REGRID Flowchart



5.8 Subroutine C_UN

Subroutine Call:

C_UN (dcal1, dcal2, ndepth, xxin, zzin, xdelt_gr, spedepth)

Summary:

Subroutine C_UN converts measurement units of input cross-shore distances, depth arrays, starting depth and the grid step size (Δx) to meters for internal calculations.

Input Variables:

dcal1	Real	Conversion Factor for Cross-Shore Distances
dcal2	Real	Conversion Factor for Water Depths
dstart	Real	Input Starting Depth
ndepth	Integer	Number of Points in Input Depth Profile
xdelt_gr	Real	Self Adjusting Cross-Shore Grid Step
xxin (points)	Real	Cross-Shore Distances
zzin (points)	Real	Corresponding Depths

Output Variables:

spedepth	Real	Input Starting Depth
xdelt_gr	Real	Self Adjusting Cross-Shore Grid Step
xxin (points)	Real	Cross-Shore Distances
zzin (points)	Real	Corresponding Depths

Local Variables:

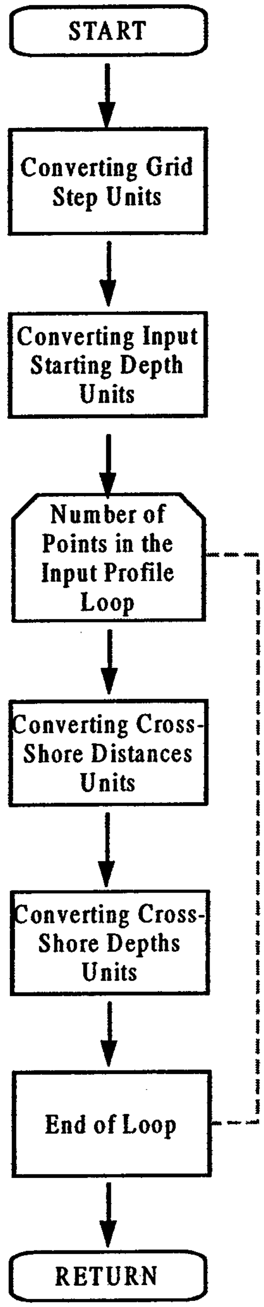
I	Integer	Loop Counter

Subroutines Called from C_UN ( ): None.

C_UN ( ) Called from Subroutines:

C_IN_DEP

Figure 9. Subroutine C_UN Flowchart



5.9 Subroutine CALC_HB3

Subroutine Call:

CALC_HB3 (dp, hrms, p_flag, hb3)

Summary:

Subroutine CALC_HB3 integrates the wave height distribution for a given root mean square wave height and calculates a term inherent to the roller dissipation function.

Input Variables:

dp	Real	Offshore Water Depth
hrms	Real	Root Mean Square Wave Height Calculation
p_flag	Logical	Weighting Factor Flag (True or False)

Output Variables:

hb3	Real	Weighting Function for Dissipation Term

Local Variables:

hhigh	Real	Maximum Wave Height
hlow	Real	Minimum Wave Height
integrat	Real	Wave Height Distribution Calculated for a Single Wave at a Specific Location

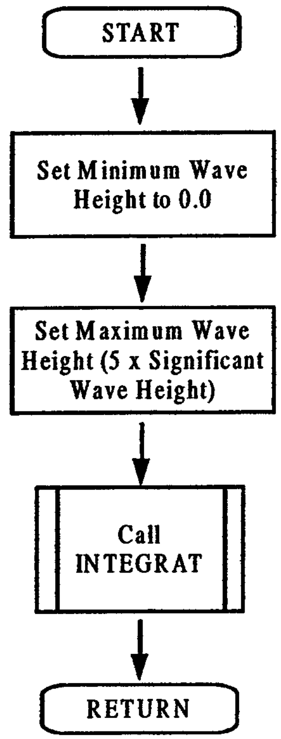
Functions Called from CALC_HB3 ( ):

INTEGRAT

CALC_HB3 ( ) Called from Subroutines:

CALCROLL
GET_DISS

Figure 10. Subroutine CALC_HB3 Flowchart



5.10 Subroutine CALCROLL

Subroutine Call:

CALCROLL (roller, hrms, dp, fqz, theta, xk, e_roller)

Summary:

Subroutine CALCROLL calculates roller energy at a point in the surf zone based on water depth and Wave Height (hrms) at that location.

Input Variables:

dp	Real	Offshore Water Depth
fqz	Real	Zero Crossing Frequency
hrms	Real	Root Mean Square Wave Height
roller	Logical	Roller Option Flag (True or False)
theta	Real	Wave Angle, Representative of Radiation Stress Angle
xk	Real	Wave Number

Output Variables:

e_roller	Real	Roller Contribution to Energy Equation

Local Variables:

c	Real	Wave Celerity
er	Real	Temporary Roller Variable
hb3	Real	Weighting Function for Dissipation Term
p_flag	Logical	Weighting Factor Flag (True or False)
z	Real	Roller Energy Multiplier

Subroutines Called from CALCROLL( ):

CALC_HB3

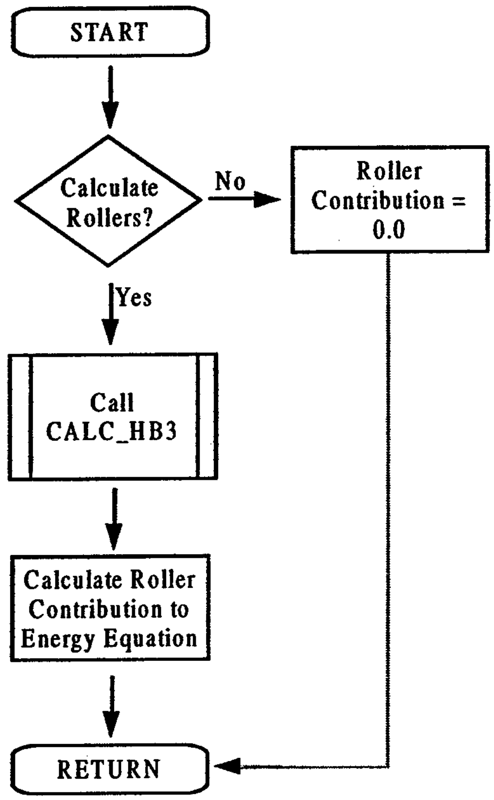
CALCROLL( ) Called from Subroutines:

GET_RHS

CALCROLL( ) Called from Functions:

F3

Figure 12. Subroutine CALCROLL Flowchart



5.11 Subroutine CALCSURF

Subroutine Call:

CALCSURF (roller, lin_stress, ehsig, wspd, wdir, tide, ydepth, nnn, dxy1, xx1, ifreq, freq1, freq2, freq, idirec, xfrom, esowm, dstart, igamma, ydetail, iyear, imonth, iday, ihour, imin, xdelt, xdelt_gr, self_st, file_spc, surf, pct, alfa, bravo, chrlie, echo, foxtrt, golf1, golf2, ihtl1, ihtl2, jgamma)

Summary:

Subroutine CALCSURF acts as the primary driver for the various subroutines, which calculate wave parameters and the longshore current across the surf zone.

Input Variables:

dstart	Real	Input Starting Depth
dxy1 (points)	Real	Corresponding Depths without Tide
ehsig	Real	Significant Wave Height from Directional Spectrum
esowm (dirNum,freqNum)	Real	Directional Wave Spectrum
freq (freqNum)	Real	Input Wave Spectrum Center Frequency
freq1 (freqNum)	Real	Beginning Frequency Bin Value
freq2 (freqNum)	Real	Ending Frequency Bin Value
iday	Integer	Input Day
idirec	Integer	Number of Direction Bins in Input Spectrum
ifreq	Integer	Number of Frequencies in Input Spectrum
igamma	Integer	Beach Orientation Rotated 90 Degrees from Original Heading Toward Beach
ihour	Integer	Input Hour
imin	Integer	Input Minute
imonth	Integer	Input Month
iyear	Integer	Input Year
lin_stress	Logical	Longshore Current Solution (True or False)
nnn	Integer	Number of Points in Input Depth Array
roller	Logical	Roller Option Flag (True or False)
self_st	Char*1	Self Start Flag (Yes or No)
tide	Real	Input Tide Level
wdir	Real	Input Wind Direction, Compass Heading Wind is Blowing From
wspd	Real	Input Wind Speed
xdelt	Real	Surf Zone Output Interval
xdelt_gr	Real	Self-Adjusting Cross-Shore Grid Step
xfrom (dirNum)	Real	Direction Array, Direction Wave Energy Comes From

xx1(points)	Real	Adjusted Cross-Shore Distances from Depth Profile
ydepth	Char*1	Input Depth Profile Used? (Yes or No)
ydetail	Char*1	Detailed Output? (Yes or No)

Output Variables:

alfa	Real	Significant Breaker Height
bravo	Real	Maximum Breaker Height
chrlie	Real	Dominant Breaker Period
echo	Real	Breaker Angle
foxtrt	Real	Longshore Current Speed and Direction
golf1	Real	Number of Surf Lines
golf2	Real	Surf Zone Width
ihtl1	Real	Wind Speed
ihtl2	Real	Wind Direction
jgamma	Integer	Temporary Value Set to Beach Orientation
pct (4)	Real	Percent of Different Breaker Types: pct (1) = Spilling pct (2) = Plunging pct (3) = Surging pct (4) = Total
surf	Logical	Flag for Low/No Surf Conditions (True or False)

Local Variables:

along (points)	Real	Horizontal Mixing Parameter from Thornton & Whittord
b	Real	Empirical Factor in Thornton & Guza Wave Breaking Model (= 1.00)
b1 (points)	Real	Bottom Slope
blong (points)	Real	Bottom Friction for Deep & Shallow Water
c	Real	Wave Celerity at Input Starting Depth
c1	Real	Eddy Viscosity Coefficient
c2	Real	Bottom Friction Coefficient
c3	Real	Radiation Stress Coefficient □ Multiple for Longshore Current Model
c4	Real	Longshore Wind Stress Coefficient □ Multiple for Longshore Current Model
cf	Real	Coefficient of Bottom Friction
Cg	Real	Wave Group Velocity
clong (points)	Real	Wind Stress Contribution to Longshore Current
convg	Logical	Energy Equation Convergence Flag
df	Real	Difference Between Adjacent Frequency Bins

distmax	Real	Farthest Offshore Distance
dp	Real	Offshore Water Depth
dth	Real	Difference Between Adjacent Directional Bins
dws_stop	Integer	Flag for Shallow Water Directional Wave Spectrum Print Control
dxy (points)	Real	Pre-Tidal Depth with Tide
eb_last	Real	Roller Dissipation Term at Farthest Point Offshore
ebtemp (points)	Real	Temporary Roller Dissipation Term Across Transect
file_spc	Char*40	File Name of Shallow Water Directional Wave Spectrum
fqd	Real	Peak Frequency at the Center of the Frequency Band
fqz	Real	Zero Crossing Frequency
ftsq2msq	Real	Conversion Factor from Feet Squared to Meters Squared
h1max	Real	Largest Significant Wave Height in the Surf Zone
h2max	Real	Largest Maximum Wave Height in the Surf Zone
hrms	Real	Root Mean Square Wave Height
htemp (points)	Real	Temporary Variable for Significant Wave Height Values
iimax	Integer	Number of Calculation Locations
irealf	Integer	Cutoff Index for Printing Shallow Water Directional Wave Spectrum
j	Real	Temporary Variable for Cross-Shore Values
j_ii	Integer	Index where Wave Probabilities come Above Threshold
j_ii2	Integer	Longshore Current Loop Variable for Outer Edge of Surf Zone
k	Real	Temporary Variable for Significant Wave Height
per	Real	Peak Period of Directional Wave Spectrum
print_spc	Integer	Flag to Print Shallow Water Wave Spectrum
ptemp (points)	Real	Percentage of Breaking Waves and Breaker Types
rk (points,4)	Real	Matrix of Percentage Breakers and Types Across the Transect
stringout	Character	Shallow Water Wave Spectrum Output String
stringsub	Character	Temporary String Variable
sum1	Real	Sum of Wave Length in the Surf Zone
temp	Real	Temporary Variable
theta	Real	Wave Angle
theta1	Real	Wave Angle at Input Starting Depth

theta2	Real	Wave Angle at Input Starting Depth
v (points)	Real	Longshore Current
vmax	Real	Maximum Positive Longshore Current
vmin	Real	Maximum Negative Longshore Current
vwind	Real	Group Wind Velocity
wdspd	Real	Wind Speed Conversion Knots to CM/S = 51.44
wid_ii	Integer	Array Location for Surf Zone Width
width	Real	Surf Zone Width
xk	Real	Wave Number
xktemp (points)	Real	Temporary Variable for Wave Number
xshift	Real	Horizontal Cross-Shore Location
xtemp (points)	Real	Temporary Variable for Cross-Shore Values

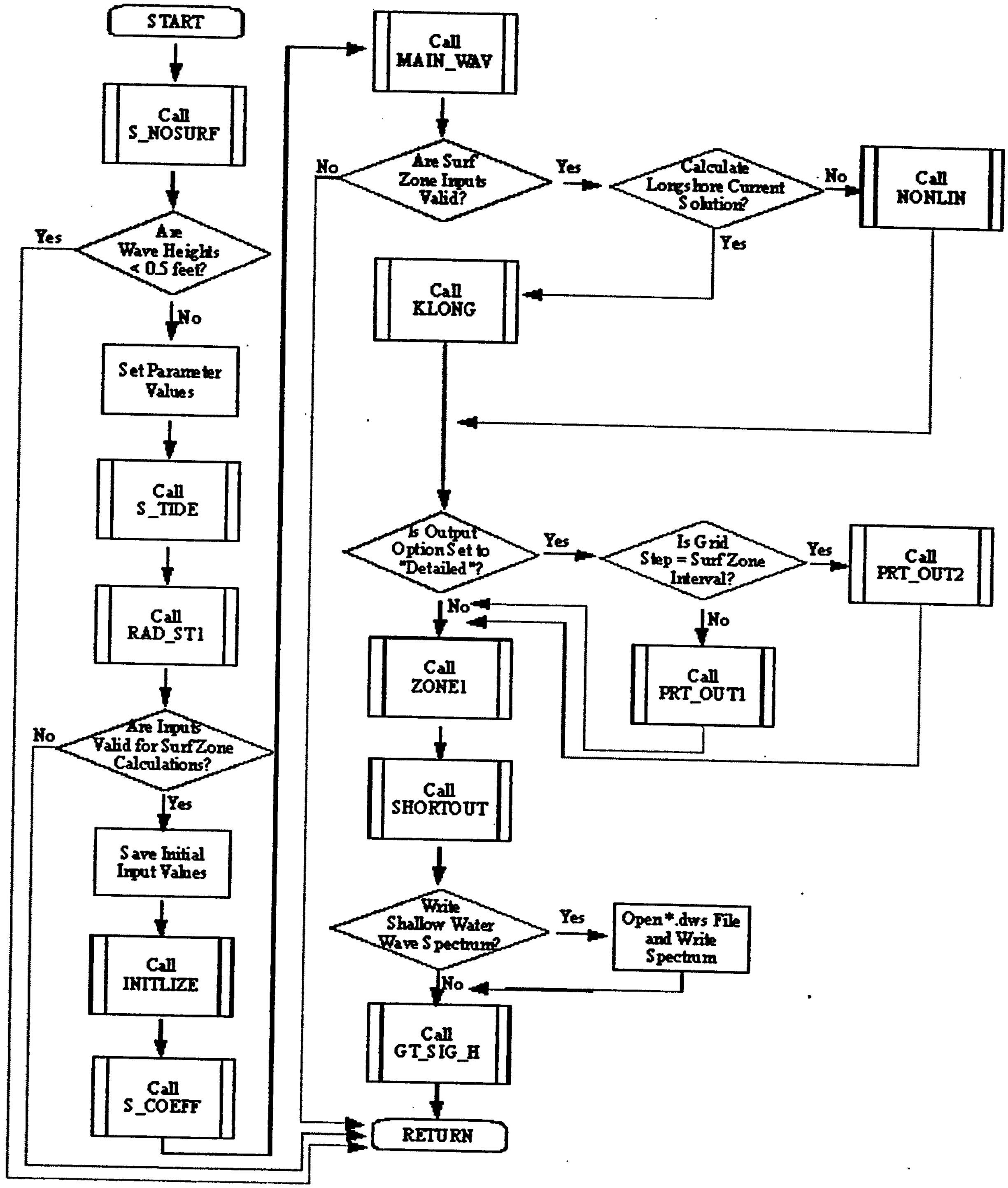
Subroutines Called from CALCSURF ( ):

GT_SIG_H
INITLIZE
KLONG
MAIN_WAV
NONLIN
PRT_OUT1
PRT_OUT2
RAD_ST1
S_COEFF
S_NOSURF
S_TIDE
SHORTOUT
ZONE1

CALCSURF ( ) Called from Subroutines:

SURF

Figure 12. Subroutine CALCSURF Flowchart



5.12 Subroutine DEPDRVR

Subroutine Call:

DEPDRVR (depname, spedepth, xdelt, ydepth, slope, gamma2, nnn, xx1, dxy1, igamma, xdelt_gr, dstart, ystr)

Summary:

Subroutine DEPDRVR is the driver routine for reconstructing the depth arrays in an optimized step size.

Input Variables:

depname	Char*40	Depth Profile File Name
dstart	Real	Input Starting Depth
gamma2	Real	Beach Orientation Compass Heading Directly Toward Beach
slope	Real	Bottom Slope
xdelt	Real	Surf Zone Output Interval
ydepth	Char*1	Usage of Input Depth Profile (Yes or No)
ystr	Char*1	Straight coast refraction flag

Output Variables:

dxy1 (points)	Real	Corresponding Depths without Tide
igamma	Integer	Beach Orientation Rotated 90 Degrees from the Original Heading Toward the Beach
nnn	Integer	Number of Points in the Input Depth Array
xdelt_gr	Real	Self-Adjusting Cross-Shore Grid Step
xx1 (points)	Real	Adjusted Cross-Shore Distances from the Depth Profile

Local Variables: None.

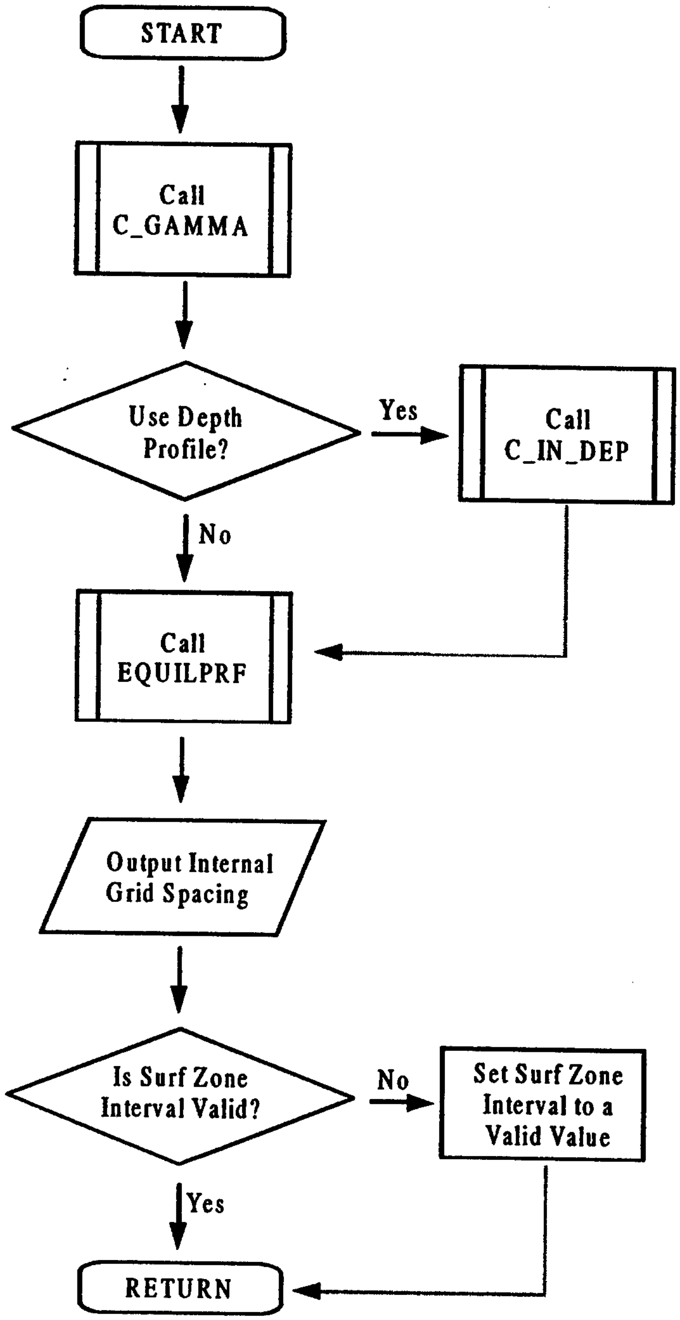
Subroutines Called from DEPDRVR ( ):

EQUILPRF
C_GAMMA
C_IN_DEP

DEPDRVR ( )Called from Subroutines:

SURF

Figure 13. Subroutine DEPDRVR Flowchart



5.13 Subroutine EQUILPRF

Subroutine Call:

EQUILPRF (wavdep, ystr, rtype, xgrd, numstep, xx1, dxy1, deepest_depth)

Summary:

Subroutine EQUILPRF constructs a depth profile for surf calculations. This equilibrium profile is based on the equation: y=Ax^(2/3), where A is a coefficient related to sediment grain size or frictional dissipation. This equation was developed by Dean (1977) from a study of more than 200 beach profiles. The "A" coefficient in the equilibrium equation has units of meters, calculations in feet require different values or conversion to feet after initial calculations. Sediment/grain types are denoted by the variable "rtype" which is the index for a value in the array of coefficients defining the following grain sizes:

1 = boulders
2 = cobble
3 = pebbles
4 = granules
5 = very coarse sand
6 = coarse sand
7 = medium sand
8 = fine sand
9 = very fine sand
10 = silt

Input Variables:

dpthoff	Real	Input Starting Depth
numstep	Integer	Number of Points in the Input Depth Array
rtype	Real	Sediment/ Grain Type
wavdep	Real	Input Wave Depth
xgrd	Real	Self-Adjusting Cross-Shore Grid Step
ystr	Character	Straight Coast Refraction Logic

Output Variables:

dxy1(points)	Real	Corresponding Depths with No Tide
xx1(points)	Real	Cross-Shore Distances

Local Variables:

a(10)	Real	Array of Sediment Coefficients
ause	Real	Actual Sediment Type Coefficient for Profile
cal1	Real	Conversion Factor (Meters)

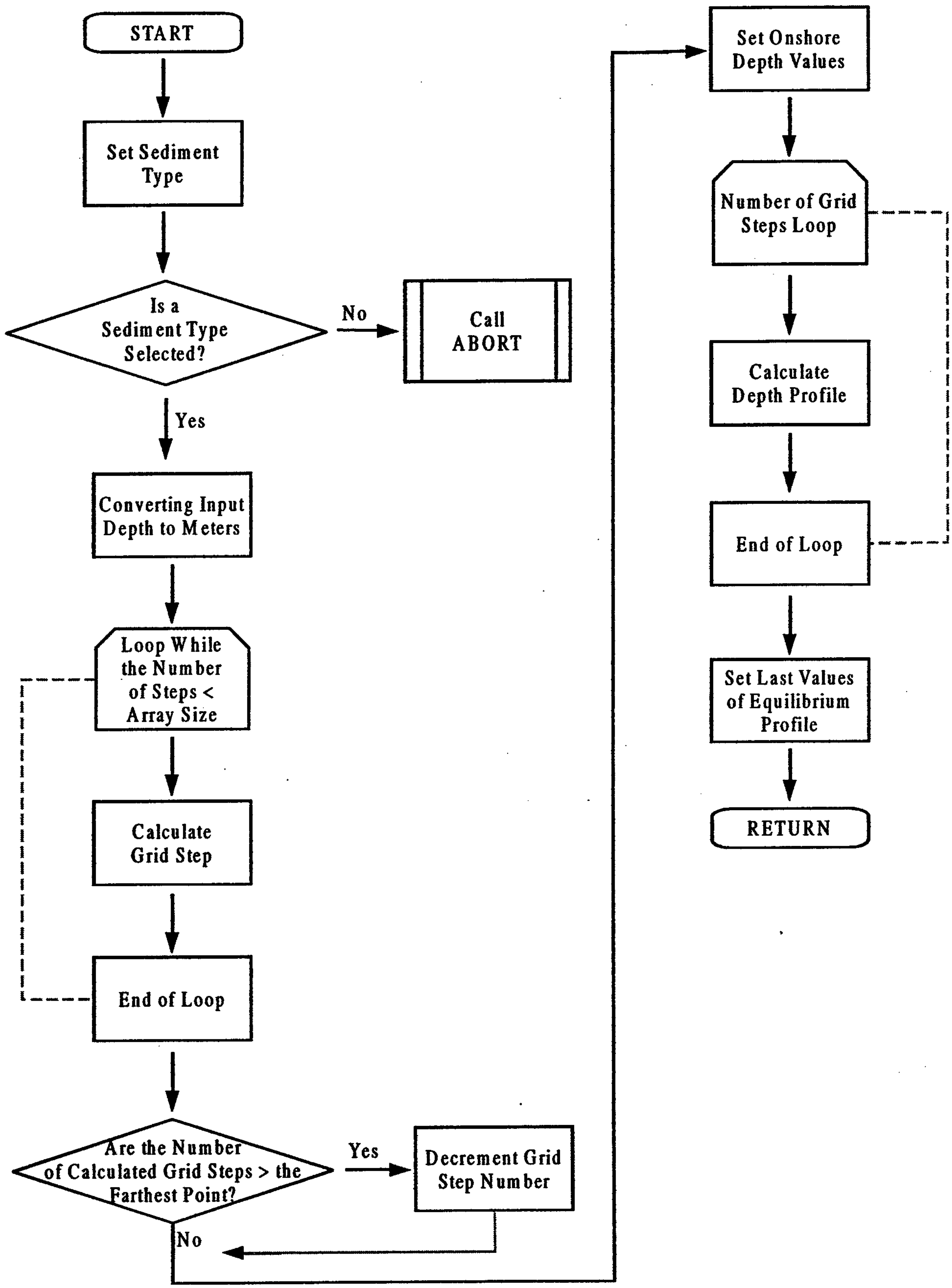
distance	Logical	Flag for Equilibrium Depth Bottom
diston	Real	Highest Onshore Distance
dpthon	Real	Highest Onshore Depth
I	Integer	Loop Counter
x	Real	Temporary Variable
xone	Real	Farthest Point Offshore
z	Real	Temporary Variable

Subroutines Called from EQUILPRF ( ): ABORT

EQUILPRF ( ) Called from Subroutines:

DEPDRVR

Figure 14. Subroutine EQUILPRF Flowchart



5.14 Subroutine GENSPEC

Subroutine Call:

GENSPEC (hsea, psea, dsea, hswell, pswell, dswell, ifreq, idirec, freq, freq1, freq2, xfrom, esowm, period, ehsig, dangle)

Summary:

Subroutine GENSPEC initializes matrices for the creation of an internally generated directional wave spectrum. This wave spectrum has 50 frequencies and 36 directions.

Input Variables:

dsea	Real	Input Direction for Sea Contribution
dswell	Real	Input Swell Direction for Internally Generated Spectrum
hsea	Real	Input Significant Wave Height for Sea Contribution to Pierson Moskowitz Equation
hswell	Real	Input Significant Wave Height for Internally Generated Spectrum
psea	Real	Input Wave Period for Sea Contribution to Pierson Moskowitz Equation
pswell	Real	Input Swell Period for Internally Generated Spectrum

Output Variables:

dangle	Real	Angle Between Directional Bins
ehsig	Real	Significant Wave Height from Directional Spectrum
esowm (dirNum,freqNum)	Real	Directional Spectrum
freq (freqNum)	Real	Input Wave Spectrum Center Frequencies
freq1 (freqNum)	Real	Beginning Frequency Bin Values
freq2 (freqNum)	Real	Ending Frequency Bin Values
idirec	Integer	Number of Direction Bins in the Input Spectrum
ifreq	Integer	Number of Frequencies in the Input Spectrum
period (freqNum)	Real	Period Array (1/Frequency)
xfrom (dirNum)	Real	Direction Array, Direction Wave Energy Comes From

Local Variables:

df	Real	Difference between Frequency Bins
idir	Integer	Direction Loop Counter
ifrq	Integer	Frequency Loop Counter

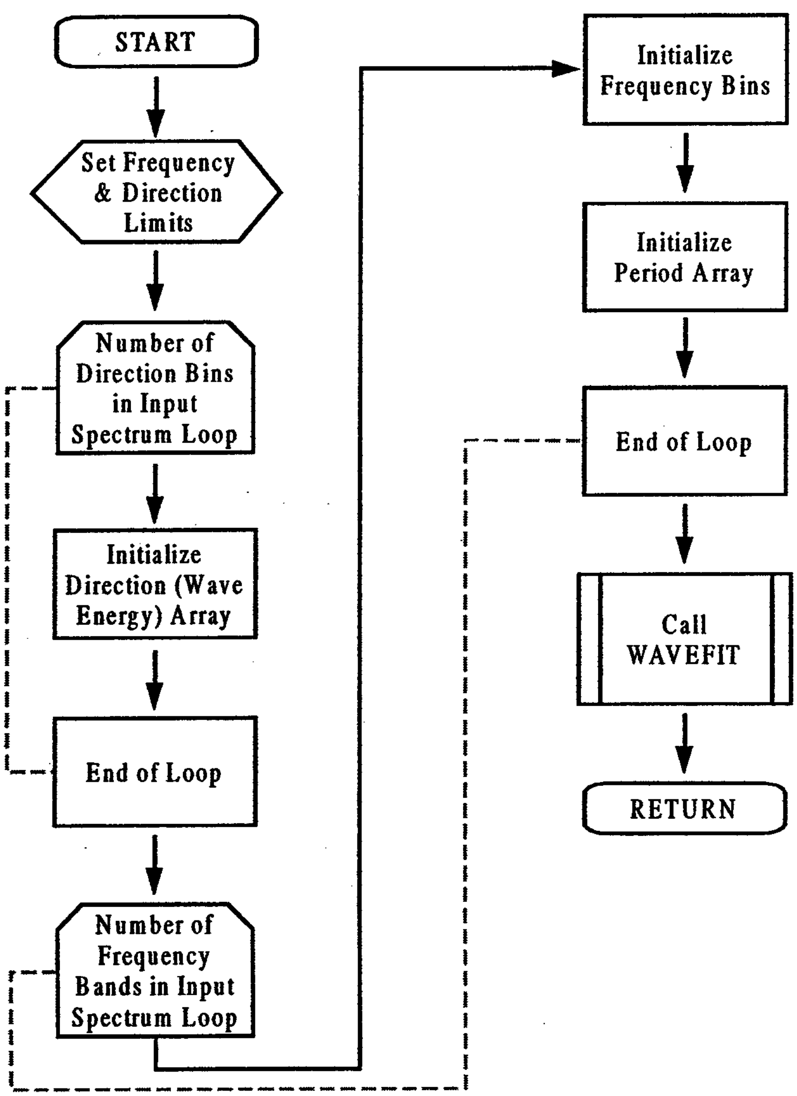
Subroutines Called from GENSPEC ( ):

WAVEFIT

GENSPEC ( ) Called from Subroutines:

SURF

Figure 15. Subroutine GENSPEC Flowchart



5.15 Subroutine GET_BRK

Subroutine Call:

GET_BRK (ii, nnn, xx1, dxy, xdelt_gr, hrms, 10, per, xoff, rk, b1, brk10, distmax, p)

Summary:

Subroutine GET_BRK calculates percentage of breakers and percent breaker type given at each point along the transect: p (1) = Spilling, p (2) = Plunging, p (3) = Surging, p (4) = 100*Sum.

Input Variables:

b1 (points)	Real	Bottom Slope
brk10	Logical	Flag for First Location where 10% of the Waves are Breaking (True or False)
distmax	Real	Farthest Offshore Distance
dxy (points)	Real	Adjusted Depths with Tide
hrms	Real	Root Mean Square Wave Height
ii	Integer	Index where Wave Probabilities Exceed Threshold
per	Real	Peak Period of Directional Wave Spectrum
rk (points,4)	Real	Matrix of Percentage Breakers and Types Across the Transect
xdelt_gr	Real	Self-Adjusting Cross-Shore Step
xoff	Real	Distance Offshore

Output Variables:

b1 (points)	Real	Bottom Slope
brk10	Logical	Flag for First Location where 10% of the Waves are Breaking (True or False)
distmax	Real	Farthest Offshore Distance
p (4)	Real	Temporary Array for Breaker Percentage Totals
rk (points,4)	Real	Percent Breaker of Each Type

Local Variables:

beta	Real	Temporary Variable for Bottom Slope

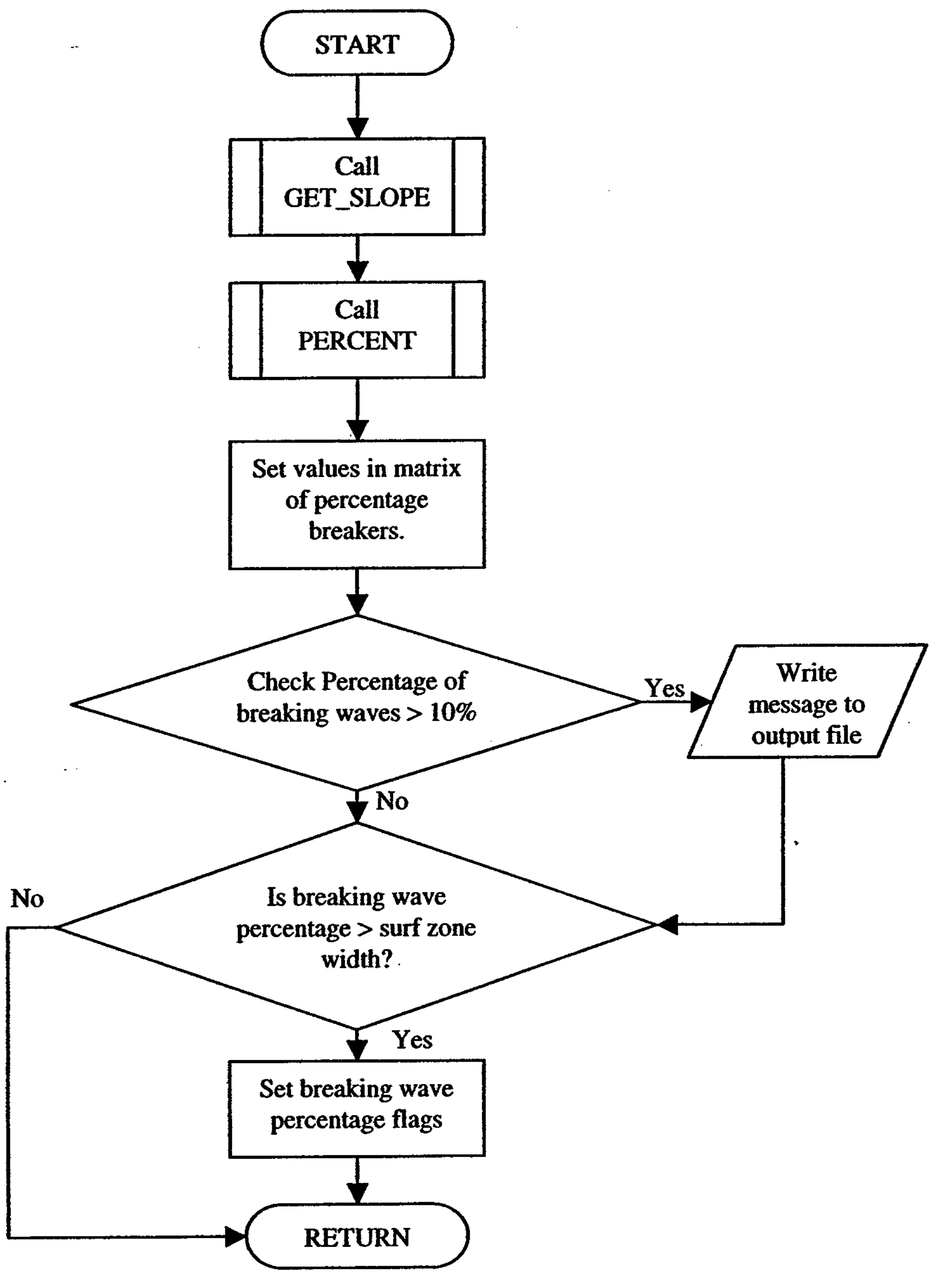
Subroutines Called from GET_BRK ( ):

PERCENT

GET_BRK ( ) Called from Subroutines:

MAIN_WAV

Figure 16. Subroutine GET_BRK Flowchart



5.16 Subroutine GET_DISS

Subroutine Call:

GET_DISS (roller, fqz, dp, hrms, p_flag, diss)

Summary:

Subroutine GET_DISS returns the wave dissipation factor. This term is based on a bore dissipation model and can include roller dissipation if selected. The dissipation term is included in the ρwave energy balance equation. The wave dissipation is given by:

$$\varepsilon_b = \frac{3\,\rho\, g\, f\sqrt{\pi}}{16h}\, H^3{}_{rms} * M * B^3$$

where ρ is density, g is gravity, f is bottom friction, h is the water depth, M is a weighting function based on hrms, and B is an empirical factor.

Input Variables:

b	Real	Empirical Factor in Thornton & Guza Wave Breaking Model = 1.00
dp	Real	Offshore Water Depth
fqz	Real	Zero Crossing Frequency
hrms	Real	Root Mean Square Wave Height
p_flag	Logical	Weighting Factor Flag (True or False)
roller	Logical	Roller Option Flag (True or False)

Output Variables:

diss	Real	Bore or Roller Dissipation Function

Local Variables:

hb3	Real	Weighting Function for Dissipation Term
z	Real	Dissipation Function

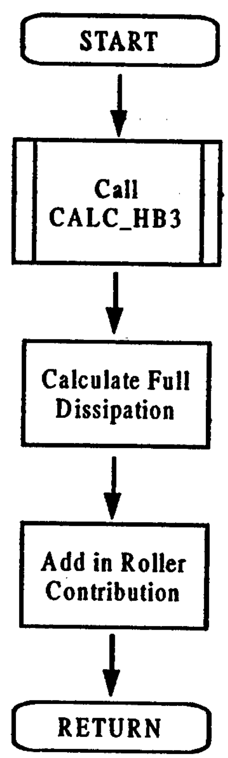
Subroutines Called from GET_DISS ( ):

CALC_HB3

GET_DISS ( ) Called from Subroutines:

GET_RHS

Figure 17. Subroutine GET_DISS Flowchart



5.17 Subroutine GET_M

Subroutine Call:

GET_M (dp, hrms, m)

Summary:

Subroutine GET_M calculates the weighting function multiplier.

Input Variables:

dp	Real	Offshore Water Depth
hrms	Real	Root Mean Square Wave Height

Output Variables:

m	Real	Multiplier

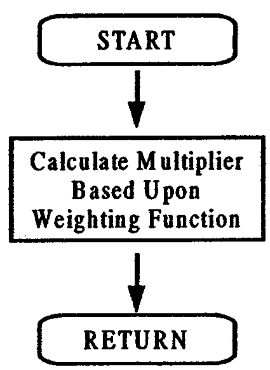
Local Variables: None.

Subroutines Called from GET_M ( ): None.

GET_M ( ) Called from Subroutines:

WEIGHTFN

Figure 18. Subroutine GET_M Flowchart



5.18 Subroutine GET_P

Subroutine Call:

GET_P (frac, p)

Summary:

Subroutine GET_P calculates the percentage of each breaker type and fills the corresponding array elements.

Input Variables:

frac (3)	Real	Temporary Array for Breaker Percentage Totals

Output Variables:

p (4)	Real	Percent of Different Breaker Types p (1) = Spilling p (2) = Plunging p (3) = Surging p (4) = Total

Local Variables:

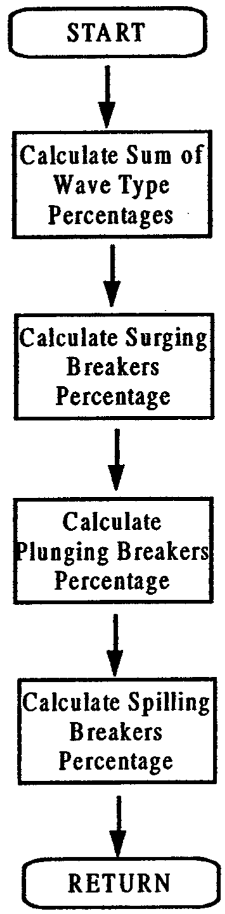
sum	Real	Temporary Variable for Total of Percentage Breakers

Subroutines Called from GET_P ( ): None.

GET_P ( ) Called from Subroutines:

PERCENT

Figure 19. Subroutine GET_P Flowchart



5.19 Subroutine GET_RHS

Subroutine Call:

GET_RHS (roller, hrms, theta, Cg, dp, xk, b, fqz, xdelt_gr, rhs, diss)

Summary:

Subroutine GET_RHS calculates the right hand side of the wave energy equation.

Input Variables:

b	Real	Empirical Factor in Breaking Model = 1.0
Cg	Real	Wave Group Velocity
dp	Real	Offshore Water Depth
fqz	Real	Zero Crossing Frequency
hrms	Real	Root Mean Square Wave Height
roller	Logical	Roller Option Flag (True or False)
theta	Real	Wave Angle, Representative of Radiation Stress Angle
xdelt_gr	Real	Self-Adjusting Cross-Shore Grid Step
xk	Real	Wave Number

Output Variables:

diss	Real	Bore or Roller Dissipation Function
rhs	Real	Right Hand Side of Energy Equation

Local Variables:

e_roller	Real	Roller Contribution to the Energy Equation
e_wave	Real	Wave Contribution to the Energy Equation
p_flag	Logical	Weighting Factor Flag (True or False)

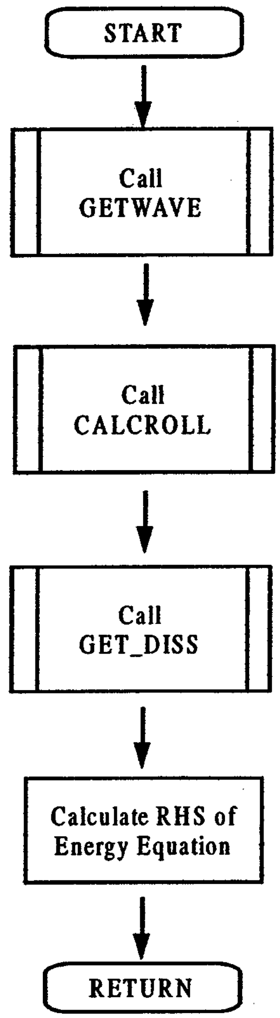
Subroutines Called from GET_RHS ( ):

CALCROLL
GET_DISS
GET_WAVE

GET_RHS ( ) Called from Subroutines:

MAIN_WAV

Figure 20. Subroutine GET_RHS Flowchart



5.20 Subroutine GET_SLOPE

Subroutine Call:

GET_SLOPE (h, x, i0, lamda, nnn, beta)

Summary:

Subroutine GET_SLOPE gets bottom slope from a depth profile for percent breaker calculations.

Input Variables:

h	Real	Array of depths associated with x (meters)
lamda	Real	Wavelength computed from wavenum()
x	Real	Array of cross-shore distance (meters)
i0	Integer	index from x where slope is computed, x(i0)
nnn	Integer	number of elements of arrays h and x with real I nfo

Output Variables:

Beta	real	bottom slope; positive up looking at beach

Local Variables:

I	integer	counter in do loops
I_last_wet	integer	index of last underwater in h(x) array
I_inshore	integer	index of x and h used for slope computation
I_offshore	integer	index of x and h used for slope computation
Once_dry	logical	used in getting i_last_wet
Slope_length	real	lamda/2.0
Sum_of_slopes	real	temp sum of slopes
Temp	real	temporary variable

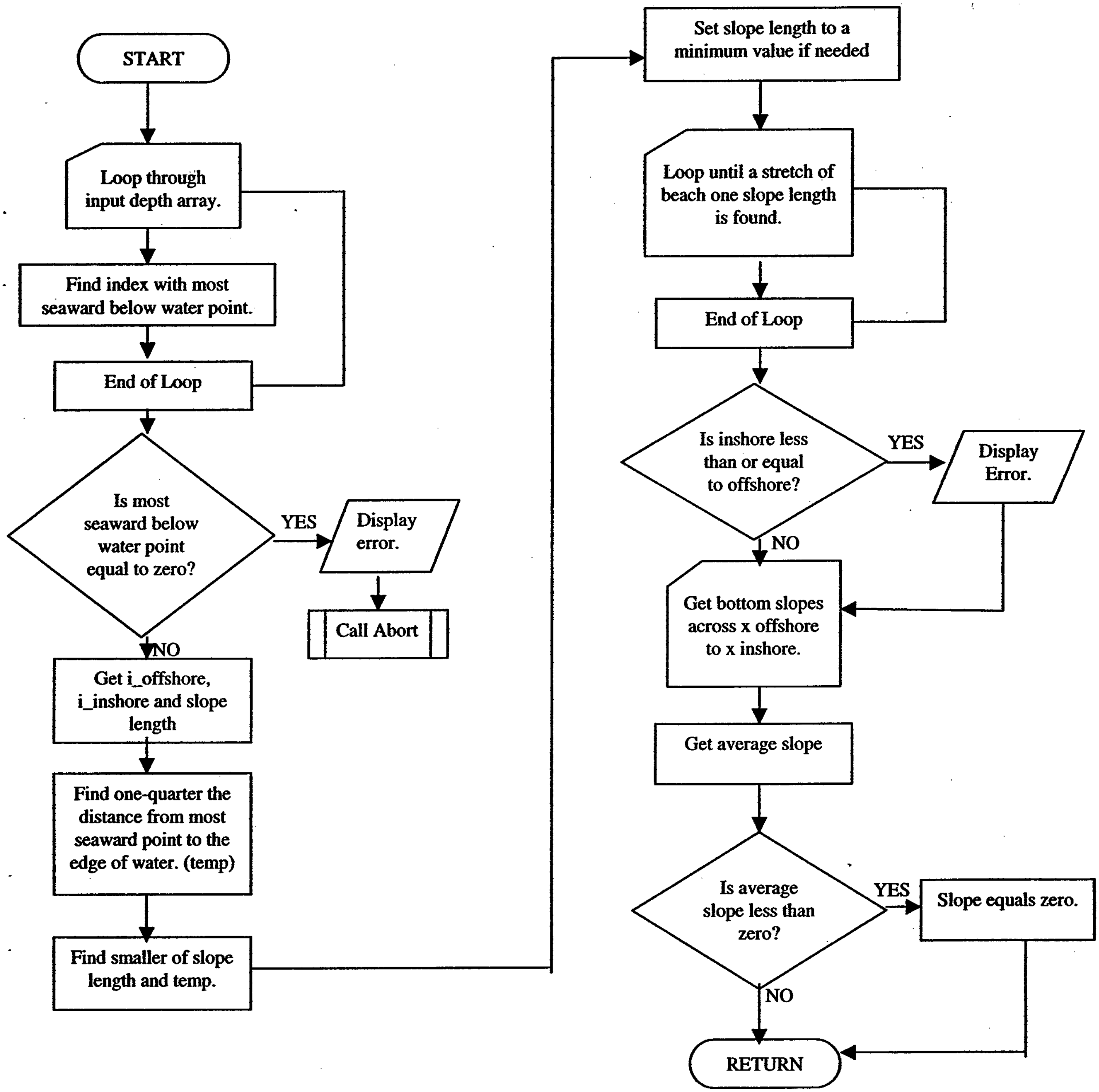
Subroutines Called from GET_SLOPE ( ):

none

GET_RHS ( ) Called from Subroutines:

SLF_STRT
GET_BRK

Figure 21. Subroutine GET_SLOPE Flowchart



5.21 Subroutine GET_WAVE

Subroutine Call:

GET_WAVE (hrms, theta, Cg, e_wave)

Summary:

Subroutine GET_WAVE calculates wave energy flux using linear wave theory. The wave energy flux is:

$$E = \frac{\rho g H^2}{8} C_g \cos \theta$$

where ρ is water density, g is gravity, H is wave height, C_g if group velocity, and θ is the wave angle.

Input Variables:

Cg	Real	Wave Group Velocity
hrms	Real	Root Mean Square Wave Height
theta	Real	Wave Angle

Output Variables:

e_wave	Real	Energy Flux

Local Variables:

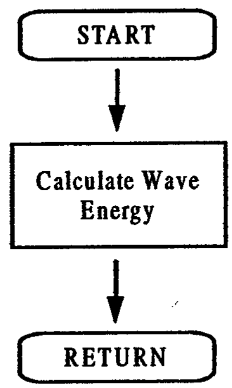
ew	Real	Wave Energy

Subroutines Called from GET_WAVE ( ): None.

GET_WAVE ( ) Called from Subroutines:

F3
GET_RHS

Figure 22. Subroutine GET_WAVE Flowchart



5.22 Subroutine GRID_FRC

Subroutine Call:

GRID_FRC (s, r, ifreq, f, idirec, d, ifreq_i, fi, idirec_i, di, si, ri)

Summary:

Subroutine GRID_FRC uses a bilinear interpolation scheme to re-grid the refraction and shoaling matrices obtained from subroutine readfrc to the same frequencies and directions associated with the directional wave spectrum obtained from the subroutine readspec.

Input Variables:

d	Real	direction array associated with input refraction and shoaling matrices (deg +CW from N)
di	Real	direction array associated with wave spectrum, array to which input refraction and shoaling matrices are interpolated (deg +CW from N)
f	Real	frequency array associated with input refraction and shoaling matrices (hertz)
fi	Real	frequency array to which input refraction and shoaling matrices are interpolated (hertz)
idirec	integer	no. of direction bands in the input refraction and shoaling matrices
idirec_i	integer	no. of direction bands to which the refraction and shoaling fields will be interpolated
ifreq	integer	no. of frequency bands in the original refraction and shoaling matrices
ifreq_i	integer	no. of frequency bands to which the input refraction and shoaling matrices will be interpolated
r(dirnum, freqnum)	real	input refraction matrix. (units are degrees +CW from N., energy from)
s(dirnum, freqnum)	real	input shoaling matrix (unitless; energy shoaling [k^2])

Output variables:

ri(dirnum, freqnum)	real	refraction matrix with same freqs and directions as input directional wave spectrum.(units are degrees (+CW from N., energy from)
si(dirnum, freqnum)	real	shoaling matrix with the same freqs and directions

as the input directional wave spectrum.
(unitless; energy shoaling [k^2])

Local Variables:

i	integer	counter
j	integer	counter
k	integer	counter
m	integer	counter
t1	real	temp
t2	real	temp

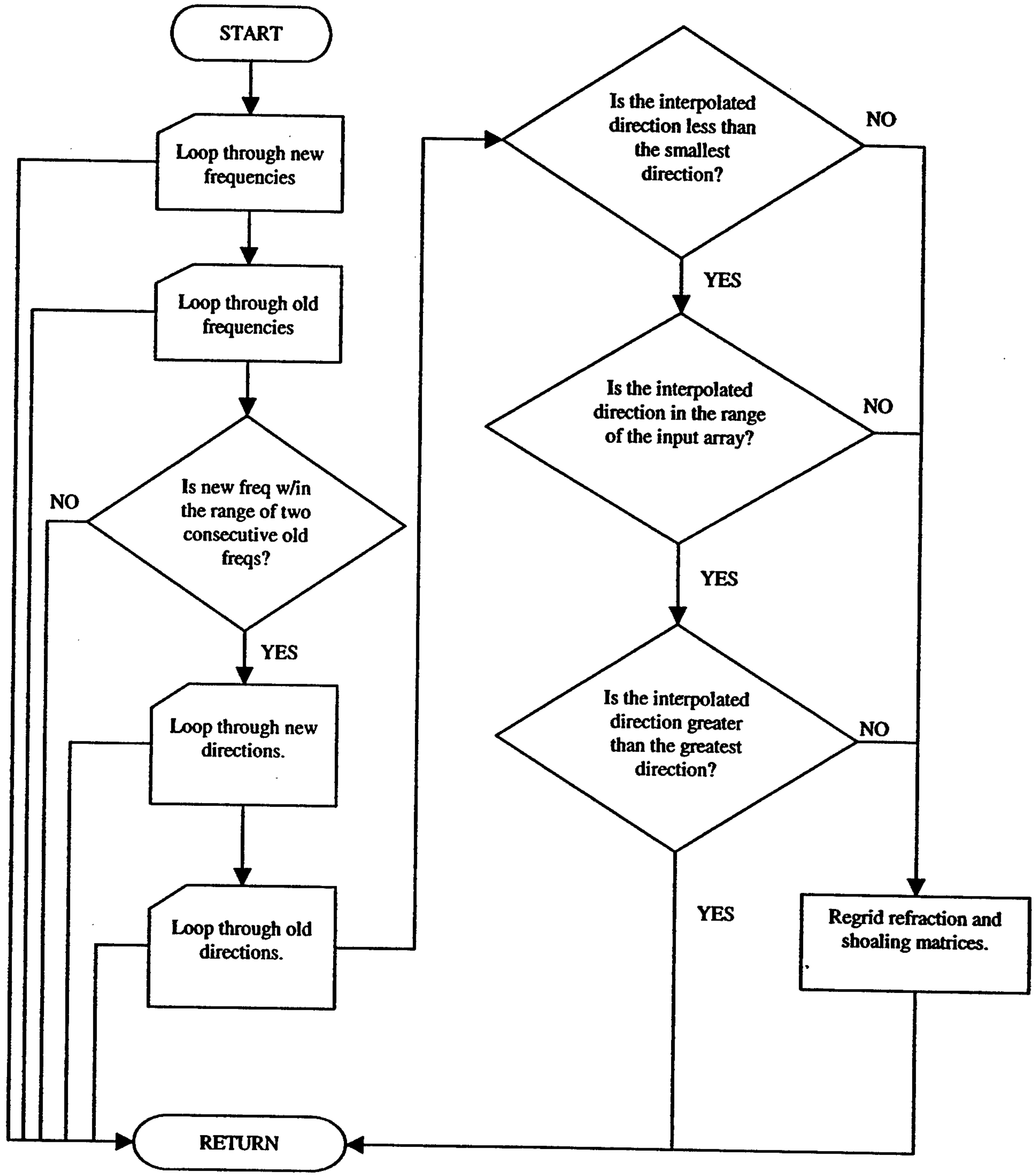
Subroutines Called from GRID_FRC ( ):

none

GRID_FRC ( ) Called from Subroutines:

Main program surf

Figure 23. Subroutine GRID_FRC Flowchart



5.23 Subroutine GRIDOUT

Subroutine Call:

GRIDOUT (ii, xoff1, xtemp, dxy, htemp, ptemp, xktemp, thetatemp, v, dp1, hout1, hmax, pbreak, brkrang, vlng1)

Summary:

Subroutine GRIDOUT linearly interpolates parameters for final output using the user defined cross-shore step width.

Input Variables:

dxy (points)	Real	Corresponding Depths with Tide
htemp (points)	Real	Temporary Variable for Significant Wave Height Values
ii	Integer	Index where Wave Probabilities Exceed Threshold
ptemp (points)	Real	Percentage of Breaking Waves and Breaker Types
xktemp	Real	Temporary Variable for Wave Number
xoff1	Real	Distance Offshore
xtemp (points)	Real	Temporary Variable for Cross-Shore Values
v (points)	Real	Longshore Current

Output Variables:

dp1	Real	Offshore Depth
hmax	Real	Maximum Wave Height / 10.0
hout1	Real	Significant Wave Height
pbreak	Real	Percentage Breaking Waves
vlng1	Real	Longshore Current Velocity
wlen	Real	Wave Length

Local Variables:

hrms1	Real	Root Mean Square Wave Height

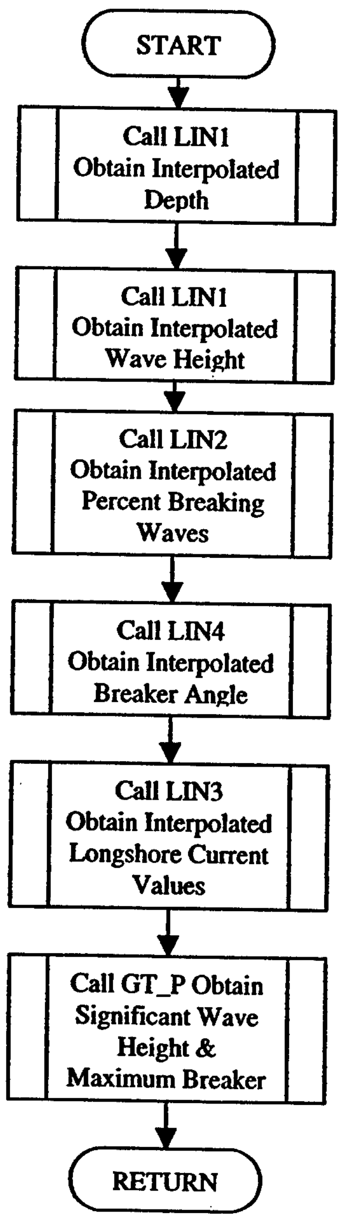
Subroutines Called from GRIDOUT ( ):

GT_P
LIN_1
LIN_2
LIN_3

GRIDOUT ( ) Called from Subroutines:

PRT_OUT1

Figure 24. Subroutine GRIDOUT Flowchart



5.24 Subroutine GT_P

Subroutine Call:

GT_ P (ii, hrms1, dp1, xktemp, hout1, hmax)

Summary:

Subroutine GT_P initializes matrices for the creation of an internally generated directional wave spectrum. This wave spectrum has 50 frequencies and 36 directions.

Input Variables:

dp1	Real	Offshore Depth
ii	Integer	Index where Wave Probabilities Exceed Threshold
hrms1	Real	Root Mean Square Wave Height
xktemp (points)	Real	Temporary Variable for Wave Number

Output Variables:

hmax	Real	Maximum Wave Height / 10.0
hout1	Real	Significant Wave Height
wlen	Real	Wave Length

Local Variables:

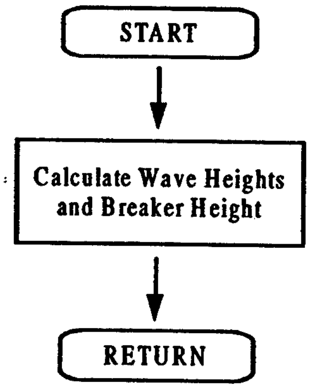
hdep	Real	Breaking Wave Height at Specific Depth

Subroutines Called from GT_P ( ): None.

GT_P ( ) Called from Subroutines:

GRIDOUT
PRT_OUT1
PRT_OUT

Figure 25. Subroutine GT_P Flowchart



5.25 Subroutine GT_SIG_H

Subroutine Call:

GT_SIG_H (ifreq, idirec, esowm, ehsig)

Summary:

Subroutine GT_SIG_H sums the energy present in the directional wave spectrum and calculates the significant wave height. The significant wave height is defined as:

$$4\sqrt{\sum e(f,\theta)}$$

Where, *e* is the directional wave spectrum.

Input Variables:

esowm (dirNum,freqNum)	Real	Directional Wave Spectrum
idirec	Integer	Number of Direction Bins in Input Spectrum
ifreq	Integer	Number of Frequencies in Input Spectrum

Output Variables:

ehsig	Real	Significant Wave Height from Directional Spectrum

Local Variables:

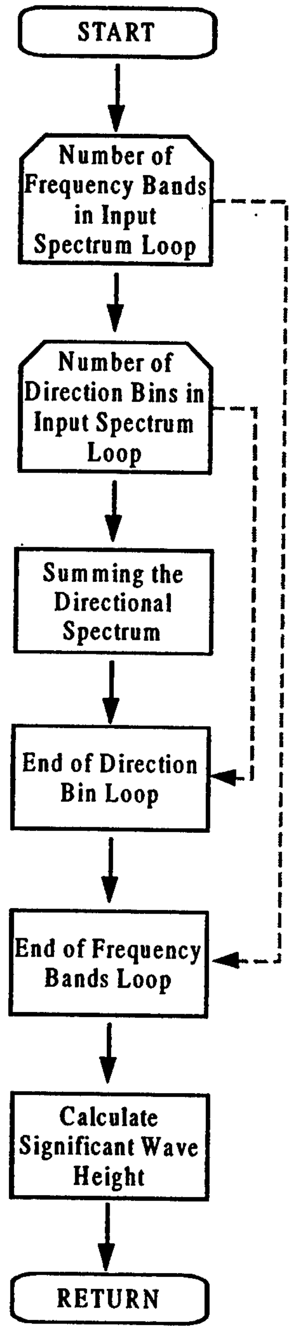
idir	Integer	Direction Loop Counter
ifrq	Integer	Frequency Loop Counter
sum1	Real	Summing Variable for Wave Height
sum2	Real	Summing Variable for Wave Height

Subroutines Called from GT_SIG_H ( ): None.

GT_SIG_H ( ) Called from Subroutines:

CALCSURF
READSPEC
WAVEFIT

Figure 26. Subroutine GT_SIG_H Flowchart



5.26 Subroutine INITLIZE

Subroutine Call:

INITLIZE (dp, fqd, Cg, xk, c)

Summary:

Subroutine INITLIZE calculates wave parameters at the farthest offshore point. Wave celerity is calculated from the dispersion relation given by:

$$\sigma^2 = g\, k\ \tanh(k\, h)$$

where, σ is the angular frequency of the wave ($2\pi/T$), g is gravity, k is wave number, and h is the local

$$C_g = 0.5C(1+\frac{2k\,h}{\sinh\ k\,h})$$

water depth. Wave group velocity is calculated from the linear wave theory relation given by: where, C is the wave celerity.

Input Variables:

dp	Real	Offshore Water Depth
fqd	Real	Peak Frequency

Output Variables:

c	Real	Wave Celerity at Input Depth & Frequency
Cg	Real	Group Velocity at Input Depth & Frequency
xk	Real	Wave Number at Input Depth & Frequency

Local Variables:

xkd	Real	Deep Water Wave Number

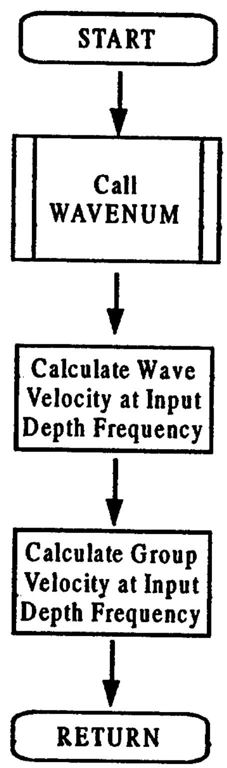
Subroutines Called from INITLIZE ( ):

WAVENUM

INITLIZE ( ) Called from Subroutines:

CALCSURF

Figure 27. Subroutine INITLIZE Flowchart



5.27 Subroutine KLONG

Subroutine Call:

KLONG (j_ii, xdelt_gr, eb_last, along, blong, long, c3, iimax, vwind, v)

Summary:

Subroutine KLONG calculates longshore current velocity using an implicit double sweep method (Tridiagonal Method) based on the work of Kraus and Larson (1991). The central difference equation is of the form:

$$a_i\ V_{i-1} +\ b_i\ V_i - c_i\ V_{i+1} = r_i$$

where, V is the longshore current velocity. The coefficients *a*, *b*, and *c* are calculated from wave parameters.

Input Variables:

along (points)	Real	Horizontal Mixing Parameter
blong (points)	Real	Bottom Friction
c3	Real	Radiation Stress Factor for Longshore Current Velocity
clong (points)	Real	Wind Stress Contribution to Longshore Current
eb_last	Real	Roller Dissipation Term Farthest Offshore
iimax	Integer	Number of Calculation Locations
j_ii	Integer	Index where Wave Probabilities Exceed Threshold
vwind	Real	Wind Driven Longshore Current Velocity
xdelt_gr	Real	Self-Adjusting Cross-Shore Grid Step

Output Variables:

v (points)	Real	Longshore Current Velocity

Local Variables:

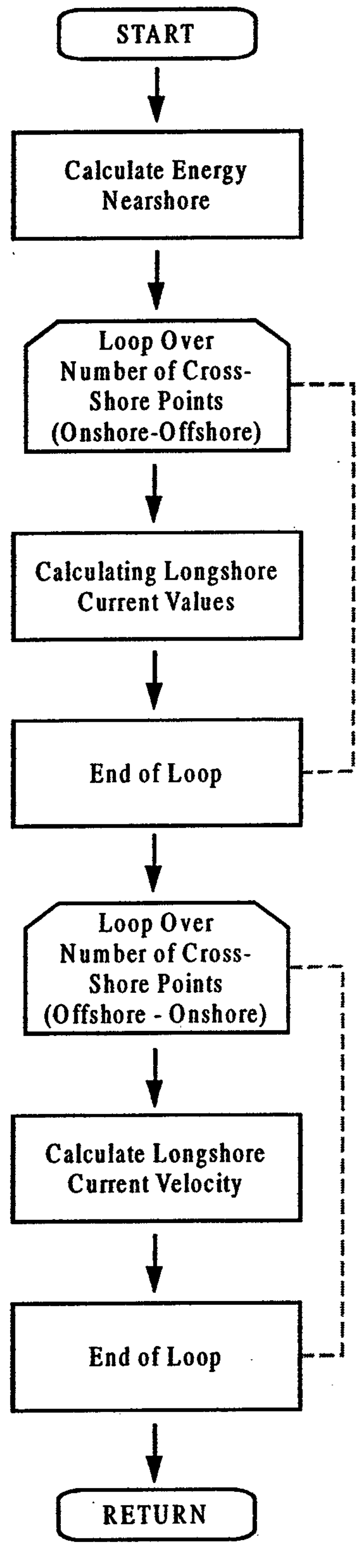
ah	Real	Temporary Variable Used in Longshore Current Calculation
bh	Real	Temporary Variables
ch	Real	Temporary Variables
dn	Real	Temporary Variables
ee (points)	Real	Array of Longshore Driving Terms
ff (points)	Real	Array of Longshore Bottom Friction
ieeff	Integer	Array Index
ii	Integer	Loop Variable
iuse	Integer	Array Index / Loop Variable
xdel2	Real	Self-Adjusting Cross-Shore Grid Step

Subroutines Called from KLONG ( ): None.

KLONG ( ) Called from Subroutines:

CALCSURF

Figure 28. Subroutine KLONG Flowchart



5.28 Subroutines LIN_1

Subroutine Call:

LIN_1 (ii, dx, dy, x, y)

Summary:

Linear interpolation routine used to scale root mean square wave height and water depth to user-defined grid step for output to the summary text file.

Input Variables:

dx (points)	Real	Input X Value
dy (points)	Real	Input Y Value
ii	Integer	Index where Wave Probabilities Exceed Threshold
x	Real	Offshore Point

Output Variables:

y	Real	Interpolated Variable

Local Variables:

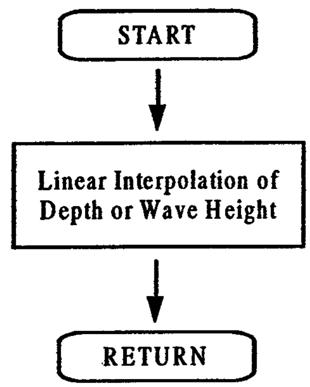
b1	Real	Intercept
m	Real	Slope
x1	Real	Cross-Shore Value
x2	Real	Previous Cross-Shore Value
y1	Real	Height Value
y2	Real	Previous Height Value

Subroutines Called from LIN_1 ( ): None.

LIN_1 ( ) Called from Subroutines:

GRIDOUT

Figure 29. Subroutine LIN_1 Flowchart



5.29 Subroutines LIN_2

Subroutine Call:

LIN_2 (ii, dx, dy, x, y)

Summary:

Linear interpolation routine used to scale percent breaking waves to user-defined grid step for output to the summary text file.

Input Variables:

dx (points)	Real	Input X Value
dy (points)	Real	Input Y Value
ii	Integer	Index where Wave Probabilities Exceed Threshold
x	Real	Offshore Point

Output Variables:

y	Real	Interpolated Variable

Local Variables:

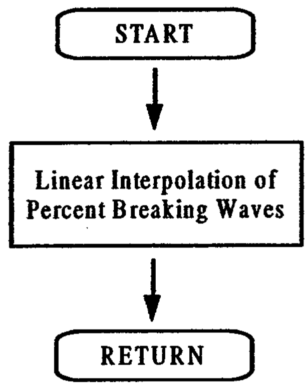
b1	Real	Intercept
m	Real	Slope
x1	Real	Cross-Shore Value
x2	Real	Previous Cross-Shore Value
y1	Real	Height Value
y2	Real	Previous Height Value

Subroutines Called from LIN_2 ( ): None.

LIN_2 ( ) Called from Subroutines:

GRIDOUT

Figure 30. Subroutine LIN_2 Flowchart



5.30 Subroutine LIN_3

Subroutine Call:

LIN_3 (ii, dx, dy, x, y)

Summary:

Linear interpolation routine used to scale longshore current velocity distribution to user-defined grid step for output to the summary text file.

Input Variables:

dx (points)	Real	Input X Value
dy (points)	Real	Input Y Value
ii	Integer	Index where Wave Probabilities Exceed Threshold
x	Real	Offshore Point

Output Variables:

y	Real	Interpolated Variable

Local Variables:

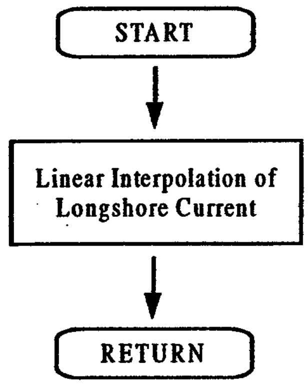
b1	Real	Intercept
m	Real	Slope
x1	Real	Cross-Shore Value
x2	Real	Previous Cross-Shore Value
y1	Real	Height Value
y2	Real	Previous Height Value

Subroutines Called from LIN_3 ( ): None.

LIN_3 ( ) Called from Subroutines:

GRIDOUT

Figure 31. Subroutine LIN_3 Flowchart



5.31 Subroutine LIN_4

Subroutine Call:

LIN_4 (ii, x, y, xi, yi)

Summary:

Linear interpolation routine used to scale breaker angle to user-defined grid step for output to the summary text file.

Input Variables:

x (points)	Real	Input X Value
y (points)	Real	Input Y Value
ii	Integer	Index in x and y arrays
xi	Real	Offshore distance

Output Variables:

yi	Real	Interpolated Variable

Local Variables:

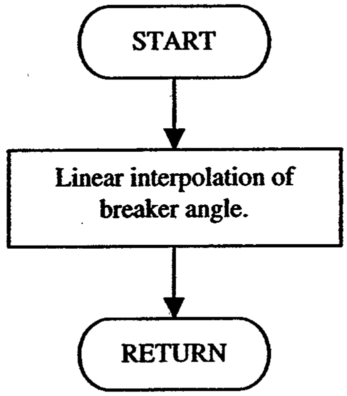
b	Real	Intercept
m	Real	Slope
x1	Real	Cross-Shore Value
x2	Real	Previous Cross-Shore Value
y1	Real	Height Value
y2	Real	Previous Height Value

Subroutines Called from LIN_4 ( ): None.

LIN_4 ( ) Called from Subroutines:

GRIDOUT

Figure 32. Subroutine LIN_4 Flowchart



5.32 Subroutine LONG1

Subroutine Call:

LONG1 (ii, c1, c2, c3, c4, dp, ebn, hrms, xk, along, blong, clong)

Summary:

Subroutine LONG1 calculates and outputs longshore current equation coefficients.

Input Variables:

c1	Real	Eddy Viscosity Coefficient
c2	Real	Bottom Friction Coefficient
c3	Real	Radiation Stress Coefficient
c4	Real	Longshore Wind Stress Coefficient
dp	Real	Offshore Water Depth
ebn	Real	Roller or Bore Term
ii	Integer	Index where Wave Probabilities Exceed Threshold
hrms	Integer	Root Mean Square Wave Height
xk	Integer	Wave Number

Output Variables:

along (points)	Real	Horizontal Mixing Parameter
blong (points)	Real	Bottom Friction Parameter
clong (points)	Real	Wave and Wind Parameters

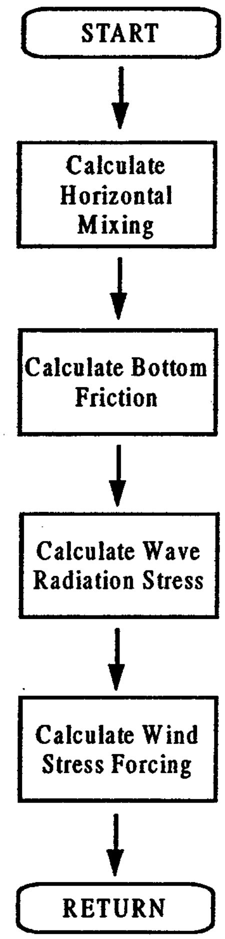
Local Variables: None.

Subroutines Called from LONG1 ( ): None.

LONG1 ( ) Called from Subroutines:

MAIN_WAV

Figure 33. Subroutine LONG1 Flowchart



5.33 Subroutine MAIN_WAV

Subroutine Call:

MAIN_WAV (roller, dxy, xx1, xshift, b, c1, c2, c3, c4, hrms, xdelt_gr, fqz, nnn, per, xk, fqd, Cg, self_st, dstart, theta, theta2, xtemp, xktemp, eb_last, htemp, ptemp, ebtemp, thetatemp, iimax, along, blong, clong, convg, distmax, rk, b1, surf, j_ii)

Summary:

Subroutine MAIN_WAV is the main driver for coordinating the iterative solution method applied to solve for the wave and current parameters. This approach is necessary because several of the parameters including wave height, wave length, wave celerity, longshore current velocity, and wave induced setup are interdependent, as well as depth dependent.

Input Variables:

b	Real	Empirical Factor in Breaking Model = 1.0
c1	Real	Mixing/Eddy Viscosity Coefficient
c2	Real	Bottom Friction Coefficient
c3	Real	Factor for Radiation Stress
c4	Real	Friction Coefficient = 0.0035
Cg	Real	Wave Group Velocity
dstart	Real	Starting Depth from Input File
dxy (points)	Real	Corresponding Depths with Tide
fqd	Real	Peak Frequency at the Center of the Frequency Band
fqz	Real	Zero Crossing Frequency
hrms	Real	Root Mean Square Wave Height
nnn	Integer	Number of Points in Input Depth Array
per	Real	Peak Period of Directional Wave Spectrum
roller	Logical	Roller Option Flag (True or False)
self_st	Char*1	Self Start Flag (Yes or No)
theta	Real	Wave Angle
xdelt_gr	Real	Self-Adjusting Cross-Shore Grid Step
xk	Real	Wave Number
xshift	Real	Horizontal Cross-Shore Location
xx1 (points)	Real	Adjusted Cross-Shore Distances from Depth Profile

Output Variables:

along (points)	Real	Horizontal Mixing Parameter
b1 (points)	Real	Bottom Slope
blong (points)	Real	Bottom Friction for Deep & Shallow Water
clong (points)	Real	Wind Stress Contribution to Longshore Current
convg	Logical	Energy Equation Convergence Flag (True or False)
distmax	Real	Farthest Offshore Distance
eb_last	Real	Roller Dissipation Term at Farthest Point Offshore
ebtemp (points)	Real	Temporary Roller Dissipation Term Across Transect
htemp (points)	Real	Temporary Variable for Significant Wave Height Values
iimax	Integer	Number of Calculation Locations
j_ii	Integer	Index where Wave Probabilities Exceed Threshold
ptemp (points)	Real	Percentage of Breaking Waves & Breaking Types
rk (points,4)	Real	Matrix of Percentage Breakers and Types Across the Transect
surf	Logical	Flag for Low/No Surf Conditions (True or False)
theta	Real	Wave Angle
theta2	Real	Wave Angle at Input Starting Depth
xktemp (points)	Real	Temporary Variable for Wave Number
xtemp (points)	Real	Temporary Variable for Cross-Shore Values

Local Variables:

brk10	Logical	Flag Variable to Find First Location Where 10% of Waves Are Breaking (True or False)
cg2	Real	Additional Wave Group Velocity
check	Real	Difference Between Wave Induced Setup Calculations
conv_count	Integer	Number of Convergence Iterations
done	Logical	Loop Control Variable for Main Wave Calculation Loop (True or False)
dp	Real	Offshore Water Depth
eb	Real	Temporary Roller Dissipation Term Across Transect

etanew (points)	Real	Wave Induced Setup Estimated at New Location
etaold (points)	Real	Wave Induced Setup Estimated at Previous Location
hrms2	Real	Wave Height for Next Onshore Grid Location
ii	Integer	Index where Wave Probabilities Exceed Threshold
ll	Real	Wave Length at Next Onshore Grid Location
l0	Real	Wave Length at Grid Cell (1) Offshore
p (4)	Real	Array for Breaker Percentage Totals
pct (4)	Real	Percent of Different Breaker Types: pct (1) = Spilling pct (2) = Plunging pct (3) = Surging pct (4) = Total
rhs	Real	Right Hand Side of Energy Balance Equation
theta0	Real	Wave Angle at Grid (1) Offshore
xoff	Real	Distance Offshore

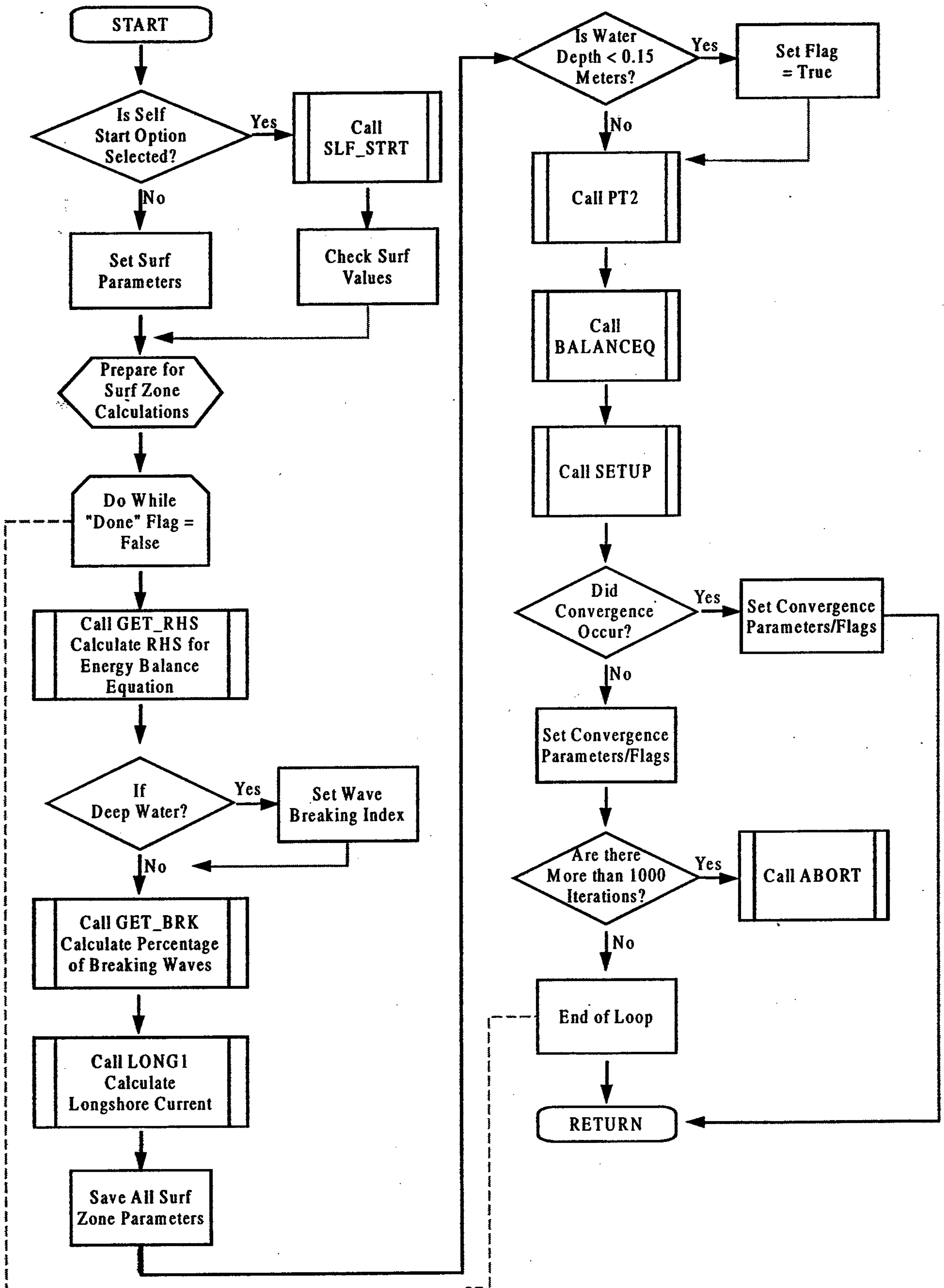
Subroutines Called from MAIN_WAV ( ):

ABORT
BALANCEQ
GET_BRK
GET_RHS
LONG1
PT_2
SLF_STRT
SETUP

MAIN_WAV ( ) Called from Subroutines:

CALCSURF

Figure 34. Subroutine MAIN_WAV Flowchart



5.34 Subroutine MDSRF1

Subroutine Call:

MDSRF1 (alfa, chrlie, pct, echo, foxtrt, jgamma, ihtl1, ihtl2, file_out)

Summary:

Subroutine MDSRF1 calculates and prints the modified surf index number to the output file.

Input Variables:

alfa	Real	Significant Breaker Height
chrlie	Real	Dominant Breaker Period
echo	Real	Breaker Angle
foxtrt	Real	Longshore Current Speed and Direction
ihtl1	Real	Wind Speed
ihtl2	Real	Wind Direction
jgamma	Integer	Temporary Variable set to Beach Orientation
pct (4)	Real	Percent of Different Breaker Types: pct (1) = Spilling pct (2) = Plunging pct (3) = Surging pct (4) = Total
file_out	Char*40	Output File Name

Output Variables: None.

Local Variables:

idir	Integer	Index for Surf Index Wind Direction
index	Integer	Breaker Type Indicator for Surf Index
ispd	Integer	Index for Surf Index Wind Speed Lookup in Modification Table
m	Integer	Temporary Variable to Rotate Direction
percent	Real	Breaker Type Percentage
srfmod	Real	Modified Surf Index from Sum of Values Resulting from Navy Modification Tables in MDSRF2 ( )
sum	Real	Running Total of Surf Index
sum1	Real	Modified Surf Index Value for Wave Angle
sum2	Real	Value for Longshore Current
temp	Real	Temporary Wave Angle Variable
theta2	Real	Rotated Wind Direction
value	Real	Modification Number

wind (3,3,8)	Real	Surf Index Wind Modification Table

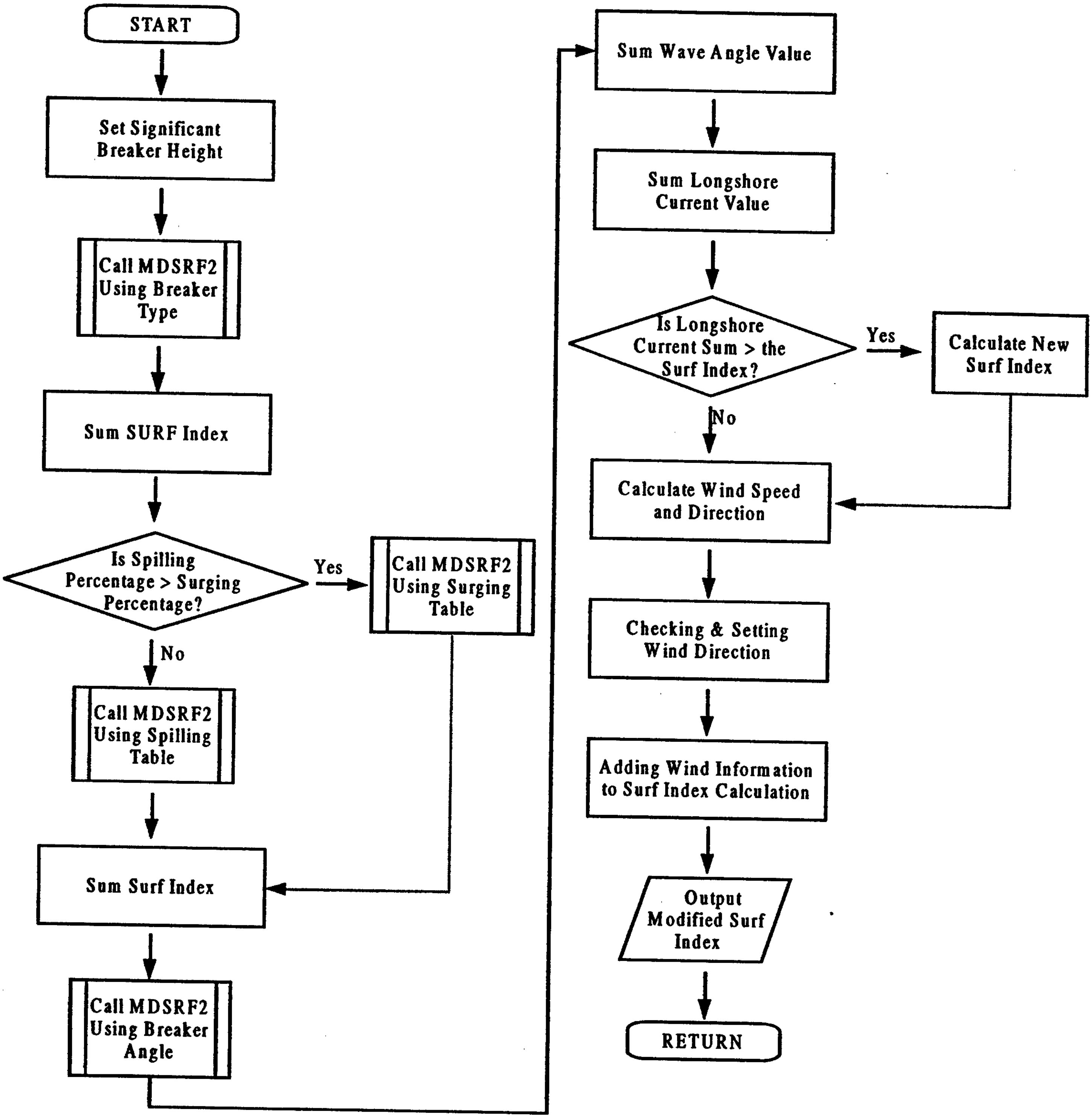
Subroutines Called from MDSRF1 ( ):

MDSRF2

MDSRF1 ( ) Called from Subroutines:

SURF

Figure 35. Subroutine MDSRF1 Flowchart



5.35 Subroutine MDSRF2

Subroutine Call:

MDSRF2 (index, xin, yin, value)

Summary:

Subroutine MDSRF2 contains the modified surf index (MSI) tables. The MSI number is calculated using a two dimensional linear interpolation by areas.

Input Variables:

index	Integer	Indicator of Breaker Type
xin	Real	X-Coordination for Surf Index Modification Matrix
yin	Real	Y-Coordination for Surf Index Modification Matrix

Output Variables:

value	Real	Returns Modified Surf Index Number

Local Variables:

i	Integer	Loop Counter or Array Index
i1	Integer	Loop Counter or Array Index
i2	Integer	Loop Counter or Array Index
ii	Integer	Loop Counter or Array Index
ix (4)	Real	All Values Set to 11.00
jy (4)	Real	Values Set to 10.0, 11.0, 11.0, 9.0
j	Integer	Loop Counter or Array Index
j1	Integer	Loop Counter or Array Index
j2	Integer	Loop Counter or Array Index
jj	Integer	Loop Counter or Array Index
temp1	Real	Temporary Variable Used for Interpolation
x (11)	Real	MSI Indices
x0 (4,11)	Real	Breaker Period Modification table
xdata	Real	Temporary Index
y (11)	Real	MSI Indices
y0 (4,11)	Real	Wave Angle Modification table
ydata	Real	Temporary Index
z (11,11)	Real	Breaker Modification Matrix
z0 (4,11,11)	Real	Whole Breaker Modification Matrix
z1 (40)-z11(40)	Real	Partial Breaker Modification Arrays

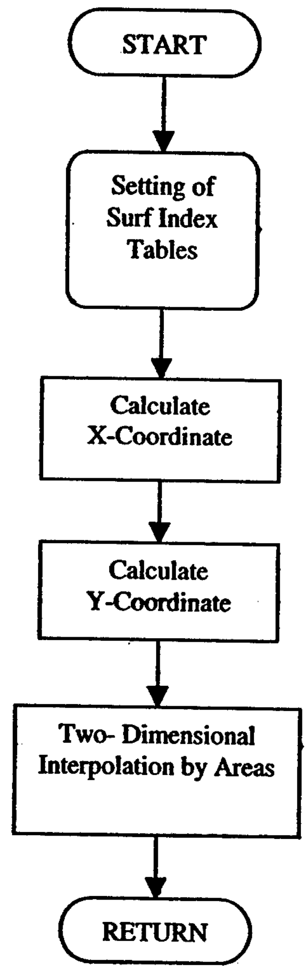
z12 (44)	Real	Partial Breaker Modification Array
zz0 (484)	Real	Equivalent to z0 (1,1,1) zz0 (1)

Subroutines Called from MDSRF2 ( ): None.

MDSRF2 ( ) Called from Subroutines:

MDSRF1

Figure 36. Subroutine MDSRF2 Flowchart



5.36 Subroutine NEW_BRK

Subroutine Call:

NEW_BRK (iimax, b1, rk, htemp, wid_ii, p2)

Summary:

Subroutine NEW_BRK calculates a new percentage of breaker types from the highest 10% of the wave heights (hrms) when the bottom slope is positive.

Input Variables:

b1 (points)	Real	Bottom Slope
htemp (points)	Real	Temporary Variable for Significant Wave Height Values
iimax	Integer	Number of Calculation Locations
rk (points,4)	Real	Matrix of Percentage Breakers and Types Across the Transect
wid_ii	Integer	Offshore Location for Surf Zone Width

Output Variables:

p2 (4)	Real	Percent of Different Breaker Types - Equivalent to pct (4) p2 (1) = Spilling p2 (2) = Plunging p2 (3) = Surging p2 (4) = Total

Local Variables:

ak1 (points)	Real	Temporary Array for Wave Height
bk1 (points)	Real	Temporary Array Breaker Type = 1 Spilling
bk2 (points)	Real	Temporary Array Breaker Type = 2 Plunging
bk3 (points)	Real	Temporary Array Breaker Type = 3 Surging
bk4 (points)	Real	Temporary Array Breaker Type = 4 Total Total Percentage of Breakers
i	Integer	Loop Counter
ii	Integer	Loop Counter
nval	Integer	Number of Positive Slope Occurrences
x1	Real	0.1 % of Highest Breakers to Examine for Type

x2	Integer	Loop Limit - Set to Top Percentage of Significant Wave Height Values

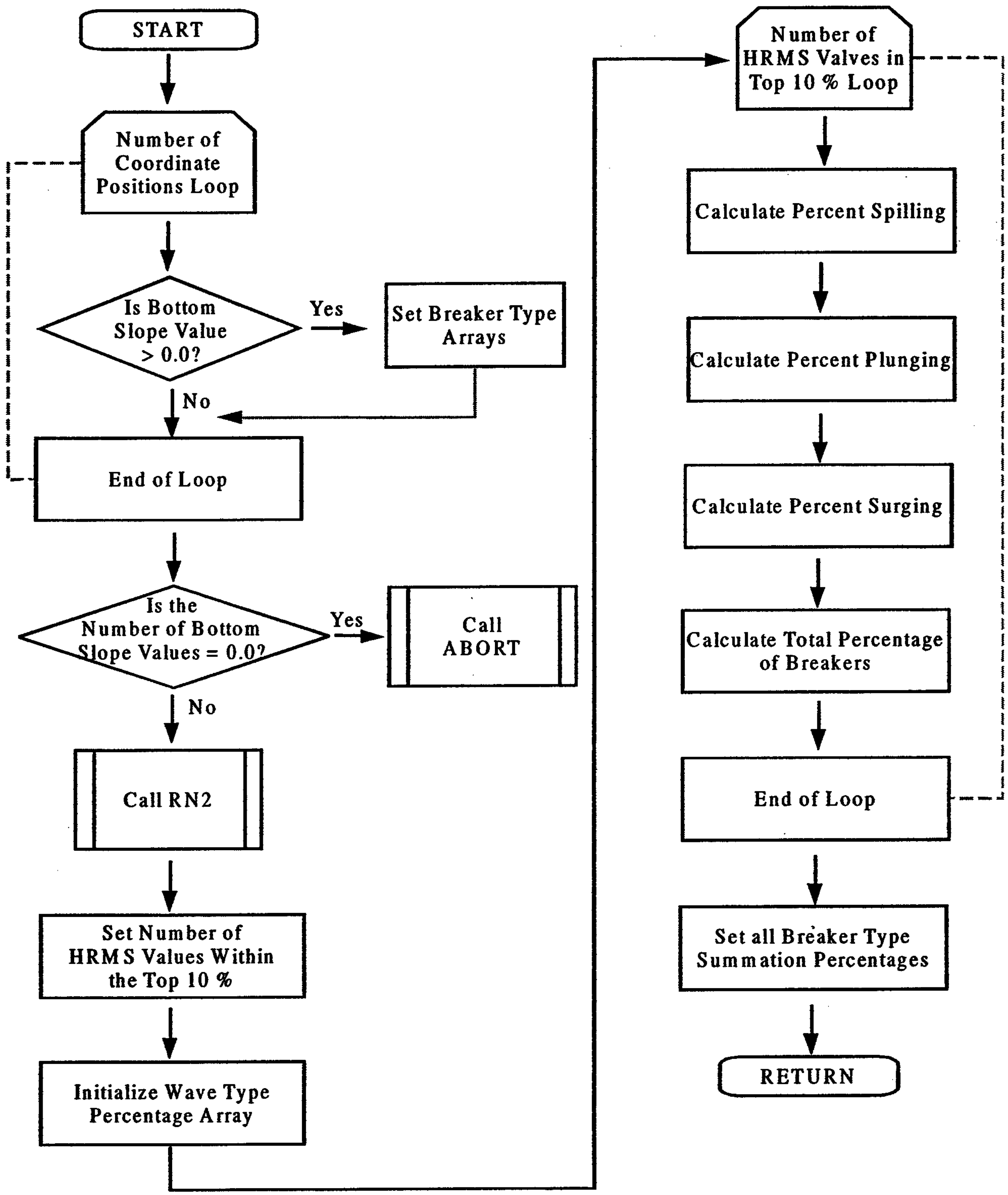
Subroutines Called from NEW_BRK ( ):

ABORT
RN2

NEW_BRK ( ) Called from Subroutines:

SHORTOUT

Figure 37. Subroutine NEW_BRK Flowchart



5.37 Subroutine PERCENT

Subroutine Call:

PERCENT (hrms, period, dp, slope, p)

Summary:

Subroutine PERCENT calculates the percentage of each type of breaking wave in the surf zone.

Input Variables:

dp	Real	Offshore Water Depth
hrms	Real	Root Mean Square Wave Height
period	Real	Peak Period
slope	Real	Bottom Slope

Output Variables:

p (4)	Real	Array of Percentage of Breaker Types pct (1) - Spilling pct (2) - Plunging pct (3) - Surging pct (4) - Total Percentage

Local Variables:

frac (3)	Real	Array for Percentage Breaker Totals
gtemp	Real	Gravity
hhigh	Real	Upper Bound of Integration
hlow	Real	Lower Bound of Integration
integrat	Real	Wave Height Distribution Calculated at a Specific Location
p_flag	Logical	Weighting Factor Flag (True or False)
param	Real	Integral Multiplier

Subroutines Called from PERCENT ( ):

GET_P

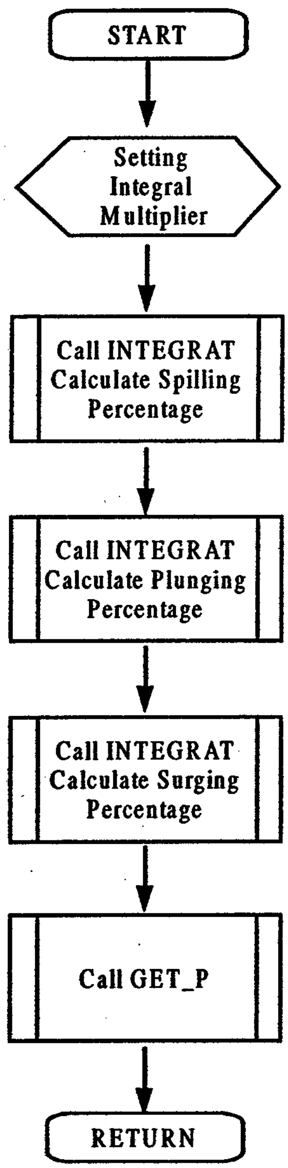
Functions Called from PERCENT ( ):

INTEGRAT

PERCENT ( ) Called from Subroutines:

GET_BRK
SLF_STRT

Figure 38. Subroutine PERCENT Flowchart



5.38 Subroutine PRT_OUT1

Subroutine Call:

PRT_OUT1 (j_ii, xdelt, iimax, dxy, xtemp, xktemp, thetatemp, htemp, ptemp, v)

Summary:

Subroutine PRT_OUT1 prints columnar data, cross-shore distributions of wave and surf parameters, to the detailed SURF output file when requested by the user. This data is interpolated to the user defined grid step, if possible.

Input Variables:

dxy (points)	Real	Corresponding Depths with Tide
j_ii	Integer	Index where Wave Probabilities Exceed Threshold
iimax	Integer	Number of Calculation Locations
htemp (points)	Real	Temporary Variable for Significant Wave Height Values
ptemp (points)	Real	Percentage of Breaking Waves & Breaker Types
v (points)	Real	Longshore Current Velocity
xdelt	Real	Surf Zone Output Interval
xktemp (points)	Real	Temporary Wave Number Array
xtemp (points)	Real	Temporary Variable for Cross-Shore Values

Output Variables: None.

Local Variables:

dp1	Real	Offshore Depth
hmax	Real	Maximum Wave Height
hout1	Real	Significant Wave Height
hrms1	Real	Root Mean Square Wave Height
ii	Integer	Array Index Number
jj	Integer	Iteration Count
pbreak	Real	Percentage Breaking Waves
vlng1	Real	Longshore Current Velocity
wlen	Real	Wave Length
xoff1	Real	Distance Offshore

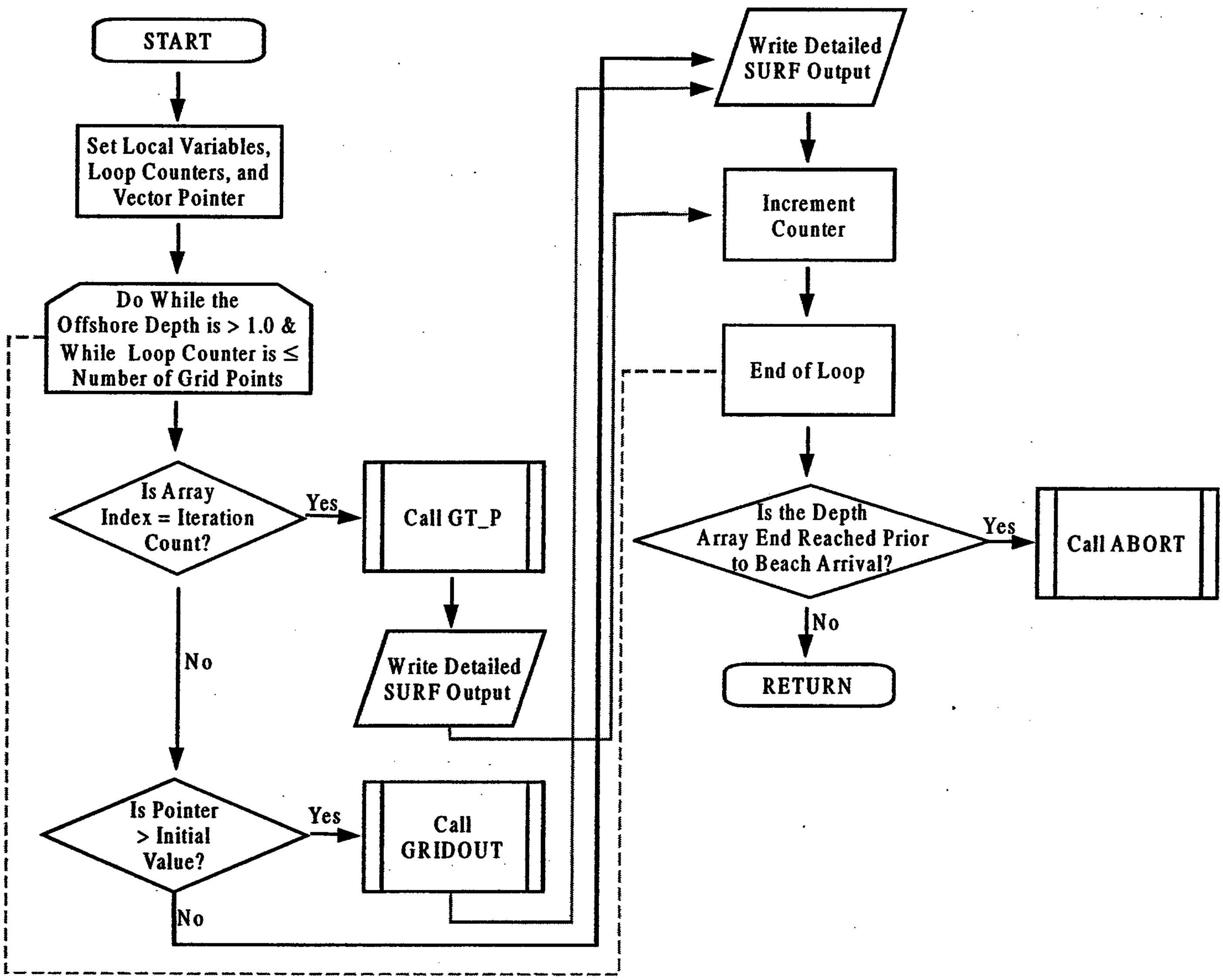
Subroutines Called from PRT_OUT1 ( ):

ABORT
GT_P
GRIDOUT

PRT_OUT1 ( ) Called from Subroutines:

CALCSURF

Figure 39. Subroutine PRT_OUT1 Flowchart



5.39 Subroutine PRT_OUT2

Subroutine Call:

PRT_OUT2 (j_ii, xdelt, iimax, dxy, xtemp, xktemp, thetatemp, htemp, ptemp, v)

Summary:

Subroutine PRT_OUT2 writes the detailed surf output.

Input Variables:

dxy (points)	Real	Corresponding Depths with Tide
j_ii	Integer	Index where Wave Probabilities Exceed Threshold
iimax	Integer	Number of Calculation Locations
htemp (points)	Real	Temporary Variable for Significant Wave Height Values
ptemp (points)	Real	Percentage of Breaking Waves and Breaker Types
v (points)	Real	Longshore Current Velocity
xdelt	Real	Surf Zone Output Interval
xktemp (points)	Real	Temporary Wave Number Array
xtemp (points)	Real	Temporary Variable for Cross-Shore Values

Output Variables: None.

Local Variables:

dp1	Real	Offshore Depth
hmax	Real	Maximum Wave Height
hout1	Real	Significant Wave Height
hrms1	Real	Root Mean Square Wave Height
ii	Integer	Array Index Number
jj	Integer	Iteration Counter
pbreak	Real	Percentage Breaking Waves
vlng	Real	Longshore Current Velocity
wlen	Real	Wave Length
xoff1	Real	Distance Offshore

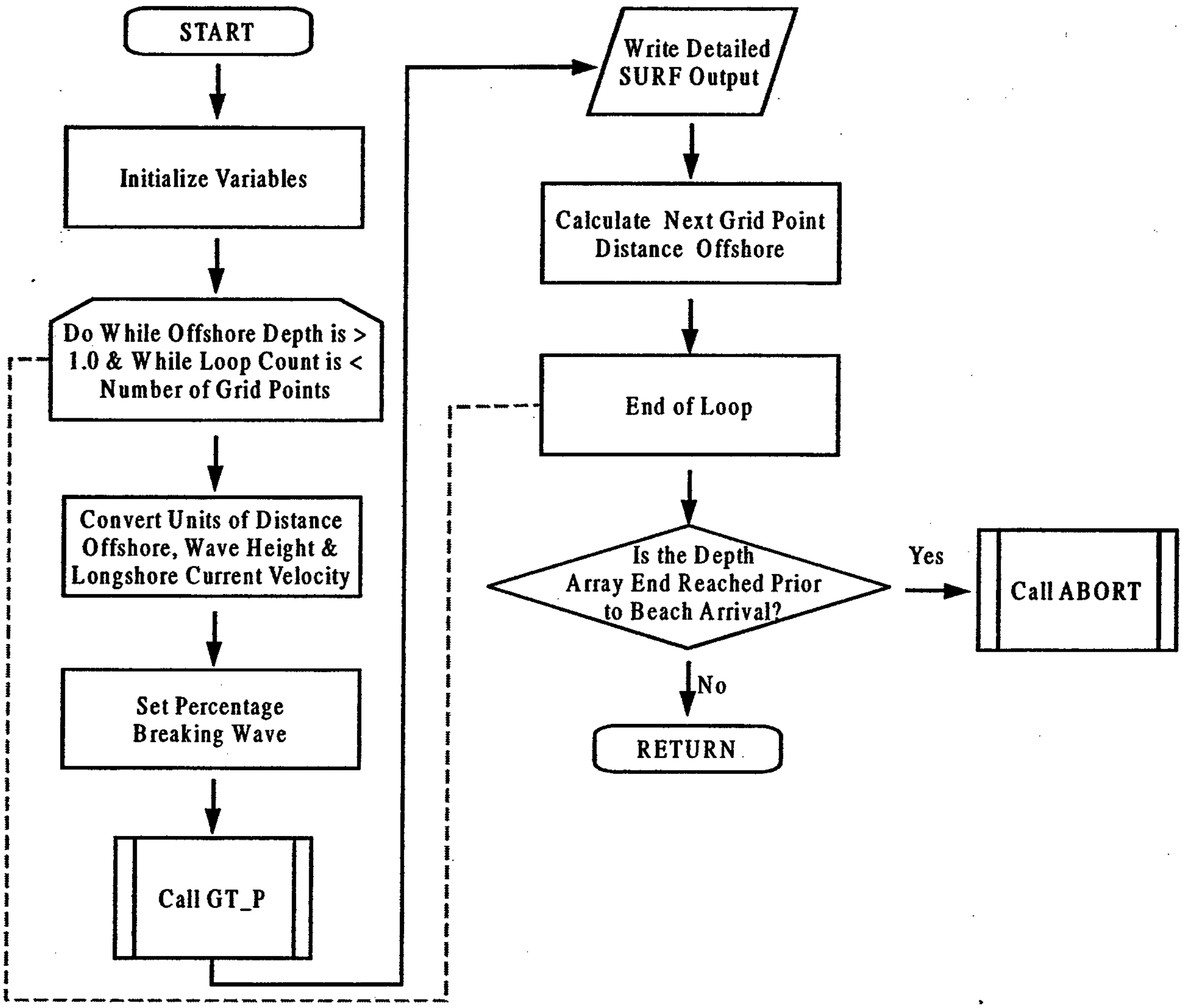
Subroutines Called from PRT_OUT2 ( ):

GT_P
ABORT

PRT_OUT2 ( ) Called from Subroutines:

CALCSURF

Figure 40. Subroutine PRT_OUT2 Flowchart



5.40 Subroutine PRT_OUT3

Subroutine Call:

PRT_OUT3 (file_dat)

Summary:

Subroutine PRT_OUT3 writes out the detailed output from the model.

Input Variables:

file_dat	Char*40	Output File name *.dat

Output Variables: None.

Local Variables:

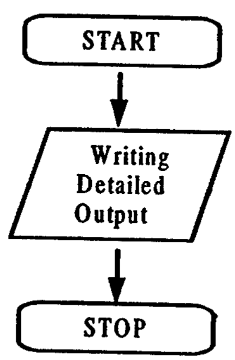
line	Char*80	Temporary String

Subroutines Called from PRT_OUT3 ( ): None.

PRT_OUT3 ( ) Called from Subroutines:

SURF

Figure 41. Subroutine PRT_OUT3 Flowchart



5.41 Subroutine PT2

Subroutine Call:

PT2 (l0, theta0, fqd, dp, theta, xk, l, Cg)

Summary:

Subroutine PT2 calculates wave parameters from linear theory relations.

$$Cg = nC \qquad \text{Group Velocity}$$

$$n = \frac{1}{2}\left[1 + \frac{2kh}{\sinh 2kh}\right]$$

$$\frac{\sin\theta}{C} = \frac{\sin\theta_0}{C_0} \qquad \text{Wave angle from Snell's law}$$

Input Variables:

dp	Real	Offshore Water Depth
fqd	Real	Peak Frequency
l0	Real	Wave Length at Offshore Point
theta0	Real	Wave Angle at Offshore Point
xk	Real	Wave Number

Output Variables:

Cg	Real	Group Velocity
l	Real	Wave Length
theta	Real	Wave Angle
xk	Real	Wave Number

Local Variables:

c	Real	Temporary Variable

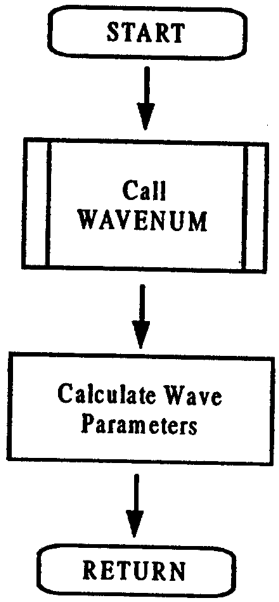
Subroutines Called from PT2 ( ):

WAVENUM

PT2 ( ) Called from Subroutines:

MAIN_WAV
SLF_STRT

Figure 42. Subroutine PT2 Flowchart



5.42 Subroutine RAD_ST1

Subroutine Call:

RAD_ST1 (ifreq, freq, idirec, xfrom, esowm, freq1, freq2, dstart, igamma, theta, hrms, surf, fqd, per, fqz)

Summary:

Subroutine RAD_ST1 searches the directional wave spectrum to identify the dominant wave frequency and sums the wave energy directed toward shore. The flux of momentum or Radiation Stress, which contributes to driving the longshore current, is calculated following Thornton and Guza

$$S_{xy}(\theta, f) = E(\theta, f)\, n(f) \sin \alpha(f) \cos \alpha(f)$$

(1986).

In the above equation S_{xy} is the Radiation Stress, E is the total energy in the directional wave spectrum, n is the ratio of wave group velocity to wave velocity, and α is the wave angle. The ratio n from linear wave theory is given by:

$$n = \frac{C_g}{C} = 0.5\,(1 + \frac{2\,k\,h}{\sinh\ k\,h})$$

where, C_g is the group velocity, C is the wave velocity or celerity, k is the wave number and h is the local water depth.

Input Variables:

dstart	Real	Input Starting Depth
esowm (dirNum,freqNum)	Real	Directional Wave Spectrum
freq (freqNum)	Real	Input Wave Spectrum Center Frequencies
freq1(freqNum)	Real	Beginning Frequency Bin Values
freq2 (freqNum)	Real	Ending Frequency Bin Values
idirec	Integer	Number of Directions in Input Spectrum
ifreq	Integer	Number of Frequencies in Input Spectrum
igamma	Integer	Beach Orientation Rotated 90 Degrees from Original Heading Toward Beach
xfrom (freqNum)	Real	Direction Array, Direction Wave Energy Comes From

Output Variables:

fqd	Real	Peak Frequency at the Center of the Frequency Band
fqz	Real	Zero Crossing Frequency
hrms	Real	Root Mean Square Wave Height
per	Real	Peak Period of Directional Wave Spectrum
surf	Logical	Flag for Low or No Surf Conditions (True or False)
theta	Real	Wave Angle

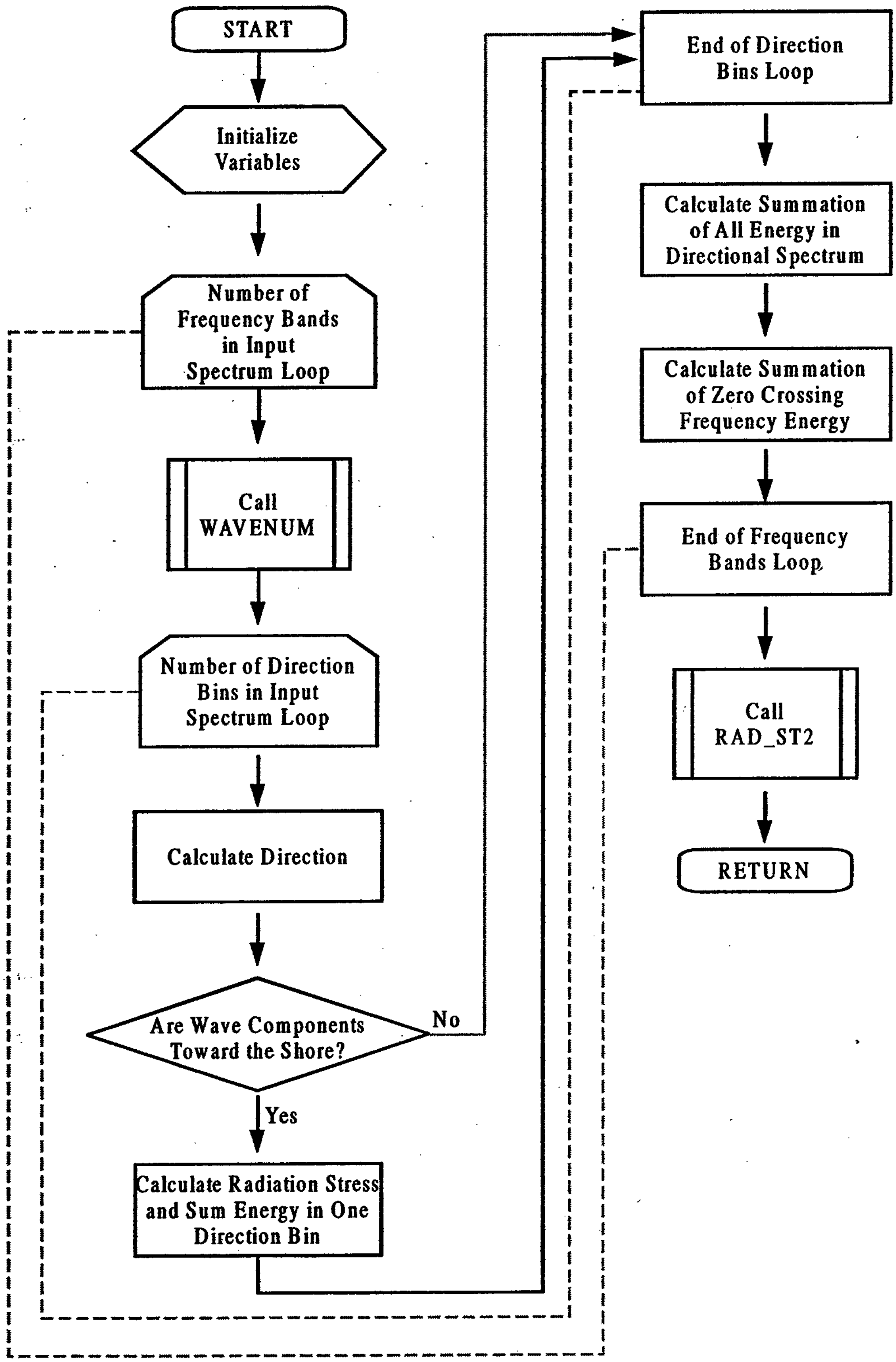
Local Variables:

direc	Real	Wave Direction
ees	Real	Spectral Density at a Particular Frequency and Direction
esum	Real	Sum of Energy in One Frequency Band Over all Directions
esumm	Real	Sum of All Energy in Directional Spectrum
frd	Real	Wave Frequency
idir	Integer	Loop Counter
ifrq	Integer	Loop Counter
m	Integer	Temporary Variable for Rotating Wave Angle
maxfrq	Integer	Frequency at Maximum Spectral Density
summax	Real	Frequency Band with Maximum Energy
sumzero	Real	Summation of Zero-Crossing Frequency Energy
sxy	Real	Radiation Stress
sxysum	Real	Sum of Radiation Stress Energy
temp	Real	Temporary Variable in Radiation Stress Calculation
temp2	Real	Temporary Variable for Frequency Band with Maximum Energy
theta2	Real	Angle Between Wave Ray and Beach Perpendicular Projection
xk	Real	Wave Number
xkd	Real	Wave Number Multiplied by the Local Water Depth

Subroutines Called from RAD_ST1 ( ):
RAD_ST2
WAVENUM

RAD_ST1 ( ) Called from Subroutines:
CALCSURF

Figure 43. Subroutine RAD_ST1 Flowchart



5.43 Subroutine RAD_ST2

Subroutine Call:

RAD_ST2 (freq, sxysum, sumzero, esumm, maxfrq, dstart, theta, hrms, surf, fqd, per, fqz)

Summary:

Subroutine RAD_ST2 calculates several parameters based on the total energy in the directional wave spectrum. A check is performed to confirm that wave energy is directed onshore before writing summary information to the output file.

Input Variables:

dstart	Real	Input Starting Depth
esumm	Real	Sum of All Energy in Directional Spectrum
freq (freqNum)	Real	Input Wave Spectrum Center Frequencies
maxfrq	Integer	Frequency at Maximum Spectral Density
sumzero	Real	Summation of Zero-Crossing Frequency Energy
sxysum	Real	Sum of Radiation Stress energy

Output Variables:

fqd	Real	Peak Frequency
fqz	Real	Zero Crossing Frequency
hrms	Real	Root Mean Square Wave Height
per	Real	Peak Period of Directional Wave Spectrum
surf	Logical	Logical Flag for Low/No Surf Conditions (True or False)
theta	Real	Wave Angle

Local Variables:

hs	Real	Significant Wave Height
sxy2	Real	Temporary Wave Energy
temp	Real	Temporary Variable for Energy
theta3	Real	Wave Angle in Degrees
xk	Real	Wave Number Calculated at Peak Frequency and Input Starting Depth
xkd	Real	Wave Number * Water Depth

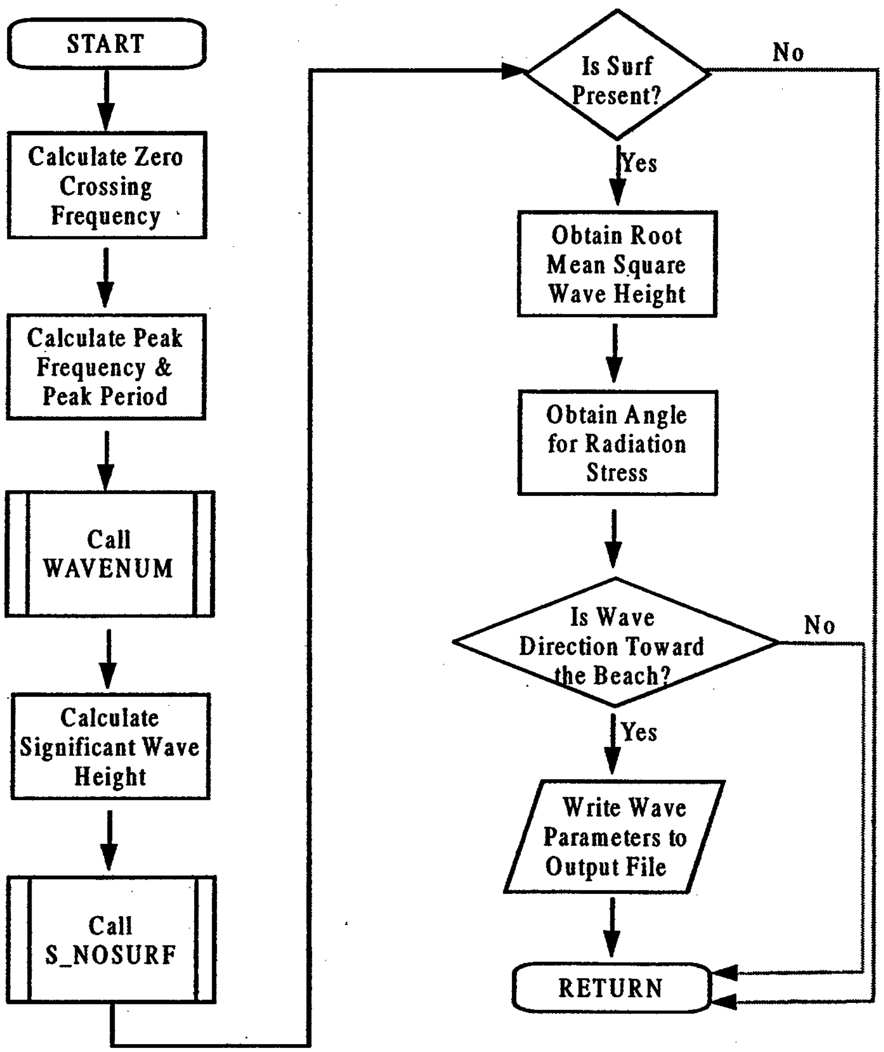
Subroutines Called from RAD_ST2 ( ):

S_NOSURF
WAVENUM

RAD_ST2 ( ) Called from Subroutines:

RAD_ST1

Figure 44. Subroutine RAD_ST2 Flowchart



5.44 Subroutine READRFRC

Subroutine Call:

READRFRC (fracname, ifreq, freq, idirec, xfrom, xcoeff, xtheta)

Summary:

Subroutine READRFRC reads refraction information from a formatted input file. The matrices contained in these files are used to shoal and refract a directional wave spectrum from an offshore point to a location where depth information is available. The number of frequency bins must not exceed 50 and the number of direction bins must not exceed 180. The directional coverage of the refraction and shoaling coefficients must range from 0 to 360 degrees. Partial coverage over a fraction of the compass (e.g. 180 degree sector) will introduce errors.

Input Variables:

fracname	Char*40	Wave Refraction File

Output Variables:

idwsdirec	Integer	Number of rows (Directions) in the Directional Wave Spectrum Matrix
idwsfreq	Integer	Number of columns (Frequencies) in the Directional Wave Spectrum Matrix
sdir (dirNum)	Real	Direction Array for each bin in the Directional Wave Spectrum
sfreq (freqNum)	Real	Center Frequency of each Directional Wave Spectrum
xcoeff (dirNum,freqNum)	Real	Wave Height Refraction Coefficients
xtheta (dirNum,freqNum)	Real	Angle Refraction Coefficients

Local Variables:

cfmatch	Logical	Flag for Center Frequency Match
cfreq (freqNum)	Real	Center Frequency of each Bin
col	Real	Number of Columns
dangle	Real	Angle Between Directional Bins
dir	Real	Number of Angles
dirin	Integer	X-Coordinates of known values
dirord	Integer	Direction of Waves 1 - Direction Waves are coming from 2 - Direction Waves are going to
dirouts (dirNum)	Real	Interpolated X-Coordinates
dirs (dirNum)	Real	Temporary Direction Wave Energy Comes From
dmatch	Logical	Flag for Directional Match

dots	Integer	Y-Coordinates of known values
dr1	Real	Initial Direction Bin
dth	Real	Temporary Angle Between Directional Bins
dum	Real	Temporary Variable
dum2	Real	Temporary Variable
dumstr	Char*80	Temporary Variable
fmatch	Logical	Flag for Frequency Match
fnum	Integer	Bin Number
found	Integer	Flag Indicator
frchk	Integer	Total Number of Frequencies
frq	Real	Number of Frequencies
I	Integer	Loop Counter
ii	Integer	Counter
icol	Integer	Number of Columns
idir	Integer	Loop Counter
idirec	Integer	Number of Rows (Directions) in the Refraction/Shoaling Matrix
ifreq	Integer	Number of Columns (Frequencies) in the Refraction/Shoaling Matrix
ifrq	Integer	Loop Counter
instat	Integer	Error Status
irow	Integer	Number of Rows
j	Integer	Loop Counter
jj	Integer	Counter
k	Integer	Counter
kk	Integer	Counter
lfreq	Real	Lower Frequency Bin Limit
lowcut	Integer	Lower Cut Off Limit
mpnt	Integer	Number of Rows divided by 2
refs (dirNum)	Real	Temporary Array
rfrtmp (dirNum,freqNum)	Real	Temporary Matrix for Reversing Wave Direction
row	Real	Number of Rows
rtmpout (dirNum)	Real	Interpolated Coordinates
sfreqin (dirNum)	Real	Temporary Frequency Array
shltmp (dirNum,freqNum)	Real	Temporary Matrix for Reversing Wave Direction
splout (dirNum)	Real	interpolated Y-Coordinates
stmpout (dirNum)	Real	Interpolated Coordinates
temp (dirNum,freqNum)	Real	Temporary Variable
temp2 (dirNum,freqNum)	Real	Temporary Variable
tmpinr (dirNum)	Real	Temporary Variable
tmpins (dirNum)	Real	Temporary Variable
ufreq	Real	Upper Frequency Bin Limit
upcut	Integer	Upper Cut Off Limit
xfrom (dirNum)	Real	Direction Wave Energy Comes From

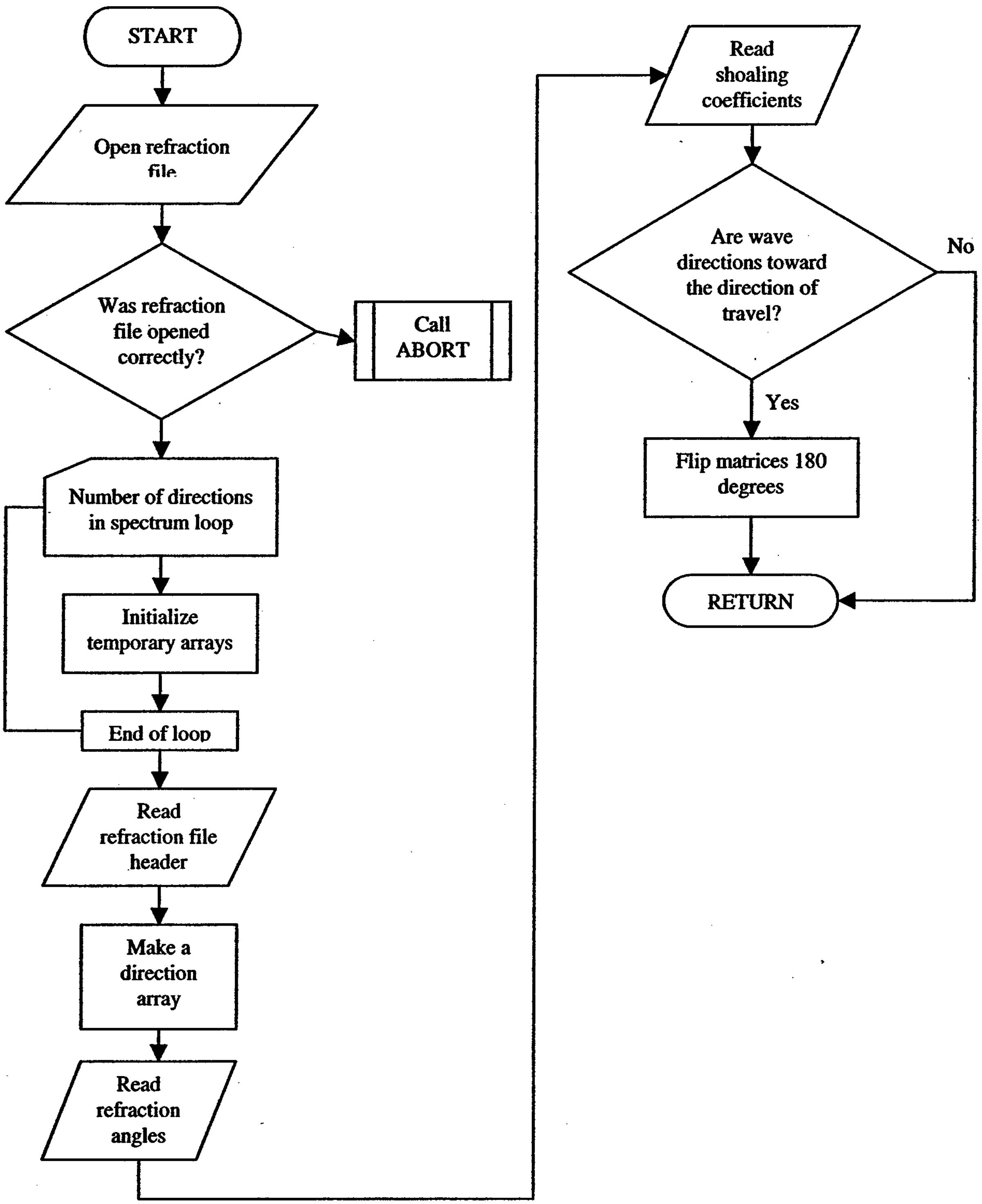
Subroutines Called from READRFRC ( ):

ABORT
GENRLSPL

READRFRC ( ) Called from Subroutines:

SURF

Figure 45. Subroutine READRFRC Flowchart



5.45 Subroutine READSPEC

Subroutine Call:

READSPEC (ifreq, idirec, Cfreq, Lfreq, Ufreq, xfrom, sowm, period, ehsig, dangle, spefile)

Summary:

Subroutine READSPEC opens and reads a directional wave spectrum file, which must conform to a specific format, but the number of frequencies and directions can vary. The maximum number of directions is 180 and the maximum number of frequencies is 50. The directions should be evenly spaced, and the frequency bins can be fixed or variable width with units of energy density (m^2/(Hz*radians)). This energy density matrix is initialized, filled, and converted to units of feet squared inside this subroutine. In addition, the direction of wave energy can be the direction FROM which waves are coming or TO which waves are going as denoted in the tenth header line by a 1 or 2 respectively. The directional wave spectrum must be defined from 0 to 360 degrees. Use of partial directional sectors (e.g. 0 to 180 degrees) will cause errors.

Input Variables: None.

Output Variables:

Cfreq (freqNum)	Real	Center Frequency Bin Limit
dangle	Real	Angle Between Directional Bins
ehsig	Real	Significant Wave Height from Directional Spectrum
esowm (dirNum,freqNum)	Real	Directional Wave Spectrum
idirec	Integer	Number of Direction Bins in Input Spectrum
ifreq	Integer	Number of Frequency Bins in Input Spectrum
Lfreq (freqNum)	Real	Lower Frequency Bin Limit
period (freqNum)	Real	Period Array (1/Frequency)
spefile	Char*40	Wave Spectrum File Name
Ufreq (freqNum)	Real	Upper Frequency Bin Limit
xfrom (dirNum)	Real	Direction Array, Direction Wave Energy Comes From

Local Variables:

col	Real	Number of Columns
df	Real	Difference between Upper & Lower Bins
dir	Real	Number of Angles
dirord	Integer	Direction of Waves 1 - Direction Waves are coming from 2 - Direction Waves are going to
dth	Real	Width of Direction Bin
dum	Char*1	Temporary Variable
dr1	Real	Initial Direction Bin
fnum	Integer	Bin Number
frq	Real	Number of Frequencies
ftsq2msg	Real	Conversion Factor
I	Integer	Loop Counter
icol	Integer	Number of Columns
idir	Integer	Direction Loop Counter
ifrq	Integer	Loop Counter
instat	Integer	Error Status
irow	Integer	Number of Rows
j	Integer	Loop Counter
mpnt	Integer	Number of Rows divided by 2
mult	Real	Temporary Calculation Variable
row	Real	Number of Rows
temp (dirNum,dirNum)	Real	Temporary Array

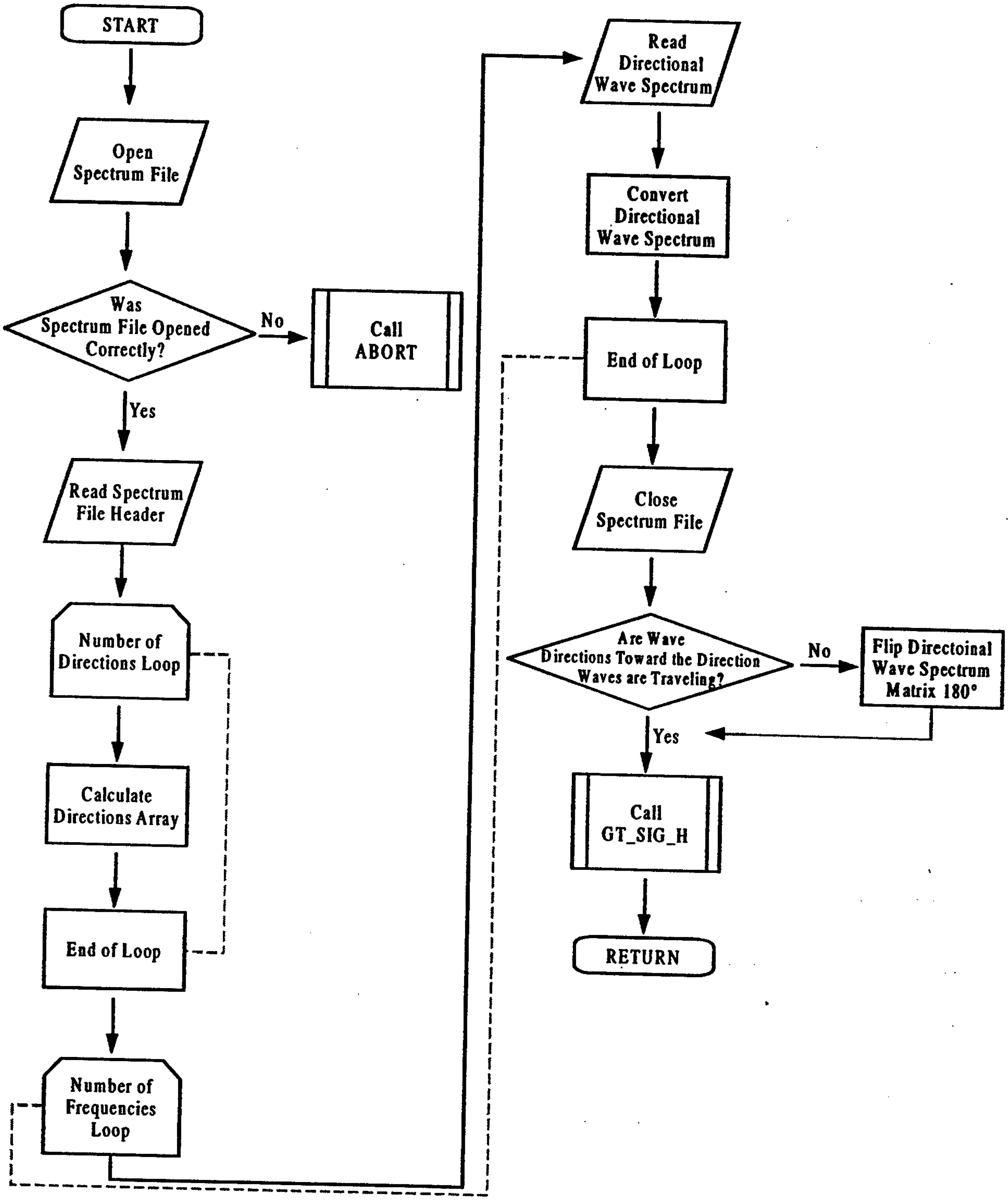
Subroutines Called from READSPEC ( ):

ABORT
GT_SIG_H

READSPEC ( ) Called from Subroutines:

SURF

Figure 46. Subroutine READSPEC Flowchart



5.46 Subroutine REFRAC

Subroutine Call:

REFRAC (idirec, ifreq, xfrom, xtheta, xcoeff, esowm, ehsig)

Summary:

For each frequency and direction bin in the input directional wave spectrum, the shallow water direction band for each deep water direction band is found. Wave energy from each deep water band is multiplied by the combined refraction/shoaling coefficient and moved into the proper shallow water band to provide a shallow water directional spectrum.

Input Variables:

dangle	Real	Angle Between Directional Bins
idirec	Integer	Number of Direction Bins in Input Spectrum
ifreq	Real	Number of Frequencies in Input Spectrum
xcoeff (dirNum,freqNum)	Real	Wave Height Refraction Coefficients
xtheta (dirNum,freqNum)	Real	Angle Refraction Coefficients

Output Variables:

ehsig	Real	Significant Wave Height from Directional Spectrum
esowm (dirNum,freqNum)	Real	Directional Wave Spectrum

Local Variables:

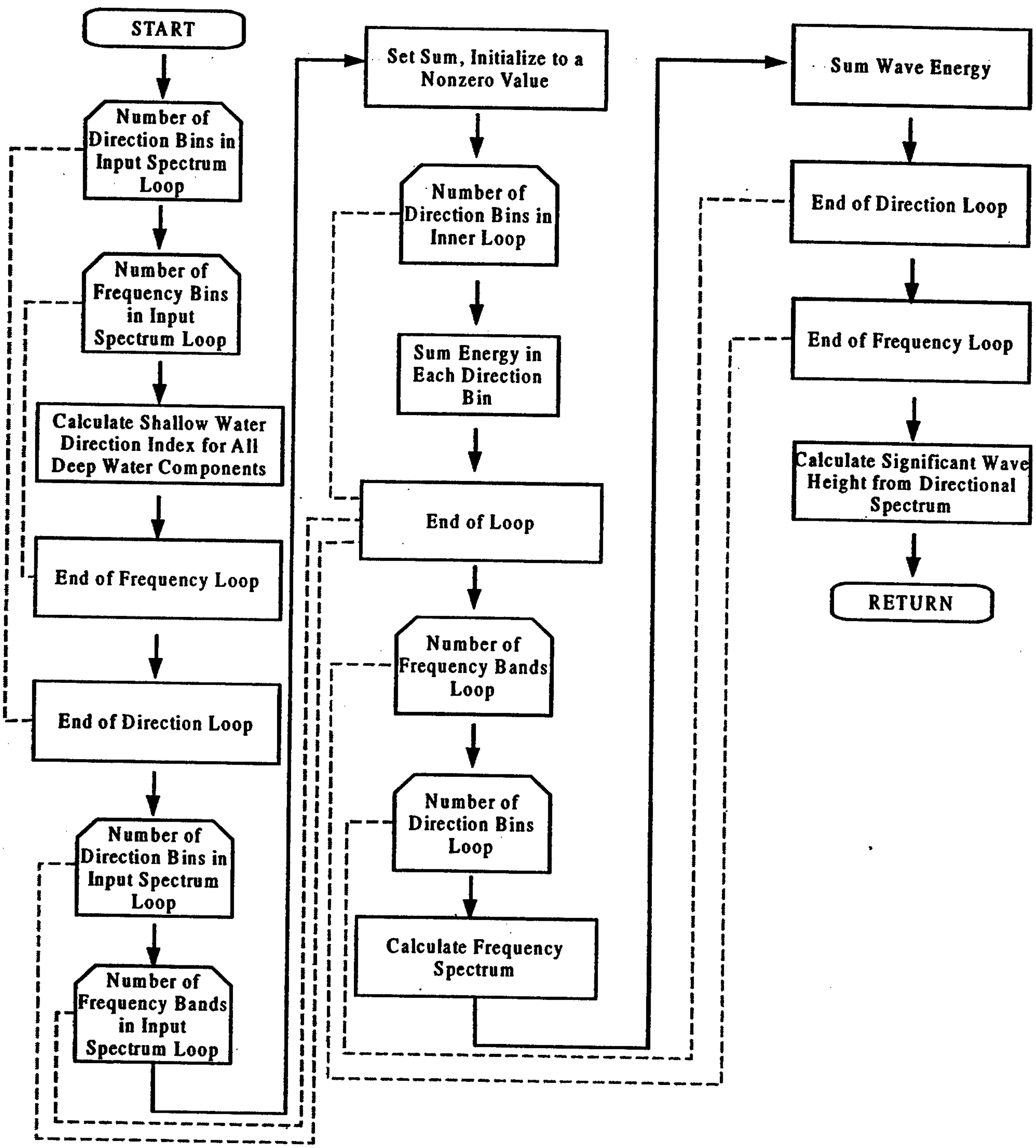
esite (dirNum,freqNum)	Real	Directional Spectrum in Shallow Water
idir	Integer	Direction Loop Counter
ifrq	Integer	Frequency Loop Counter
itemp	Integer	Temporary Wave Angle Variable
itheta (dirNum,freqNum)	Integer	Shoreward Energy Spectrum
jdir	Integer	Loop Variable
mtemp	Integer	Temporary Wave Angle Variable
sum	Real	Temporary Wave Energy Summation Variable
sum2	Real	Temporary Wave Energy Summation Variable
ytheta	Real	Temporary Wave Angle Variable

Subroutines Called from REFRAC ( ): None.

REFRAC ( ) Called from Subroutines:

SURF

Figure 47. Subroutine REFRAC Flowchart



5.47 Subroutine RN2

Subroutine Call:

RN2 (n, x, y1, y2, y3, y4)

Summary:

Subroutine RN2 calculates percentages of each type of breaker in the surf zone.

Input Variables:

n	Integer	Number of Waves Considered Breaking on a Positive Bottom Slope
x (points)	Real	Temporary Significant Wave Height Array
y1 (points)	Real	Spilling Breaker Type
y2 (points)	Real	Plunging Breaker Type
y3 (points)	Real	Surging Breaker Type
y4 (points)	Real	Total Number of Breakers

Output Variables:

y1 (points)	Real	Spilling Array Breaker Type
y2 (points)	Real	Plunging Array Breaker Type
y3 (points)	Real	Surging Array Breaker Type
y4 (points)	Real	Total Array Breaker Type

Local Variables:

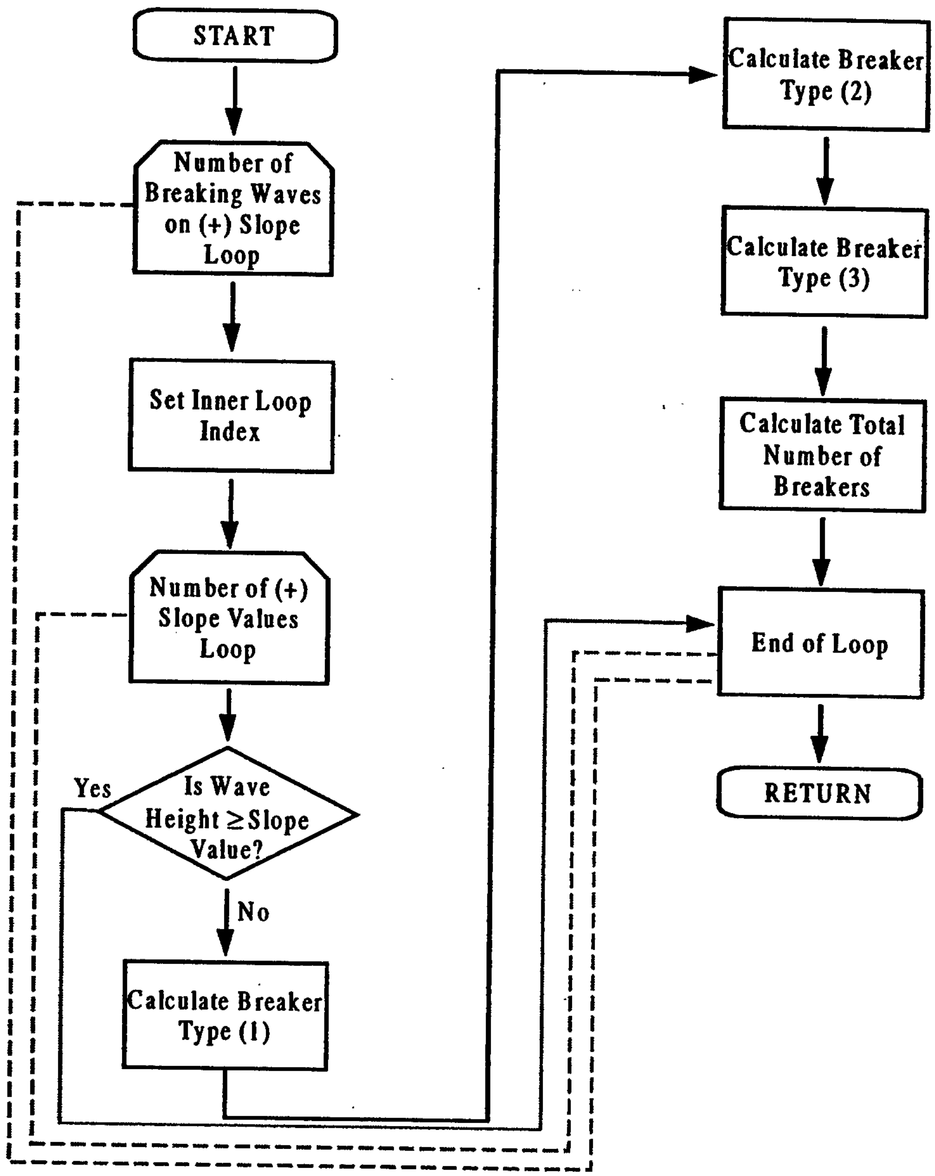
hold	Real	Temporary Variable Used for Repositioning
i	Integer	Loop Counter
j	Integer	Loop Counter
js	Integer	Loop Starting Index
m	Integer	Number of Waves Considered Breaking on a Positive Slope

Subroutines Called from RN2 ( ): None.

RN2 ( ) Called from Subroutines:

NEW_BRK

Figure 48. Subroutine RN2 Flowchart



5.48 Subroutine S_COEFF

Subroutine Call:

S_COEFF (dp, fqd, hrms, theta, c, xk, wdir, igamma, wdspd, c1,c2, c3, c4, cf, vwind)

Summary:

Subroutine S_COEFF calculates several parameters in the longshore current equation including the Radiation Stress, the bottom stress, and the wind stress. A check is performed to assure that wave induced motion is not dominated by wind effects and a warning message is written to the output file if this condition is violated. An assumption is made that if the wave induced orbital velocity is greater than the wind-forced component of the longshore current, the local conditions are wave dominated.

Input Variables:

c	Real	Wave Celerity at Input Starting Depth
dp	Real	Water Depth Offshore
fqd	Real	Peak Frequency from Directional Spectrum
hrms	Real	Root Mean Square Wave Height
igamma	Integer	Beach Orientation, Compass Heading Directly Toward Beach
theta	Real	Wave Angle
wdir	Real	Input Wind Direction Compass Heading
wdspd	Real	Input Wind Speed
xk	Real	Wave Length at Input Starting Depth

Output Variables:

c1	Real	Mixing/Eddy Viscosity Coefficient
c2	Real	Bottom Friction Coefficient
c3	Real	Factor for Radiation Stress
c4	Real	Friction Coefficient
vwind	Real	Wind Driven Longshore Current Velocity

Local Variables:

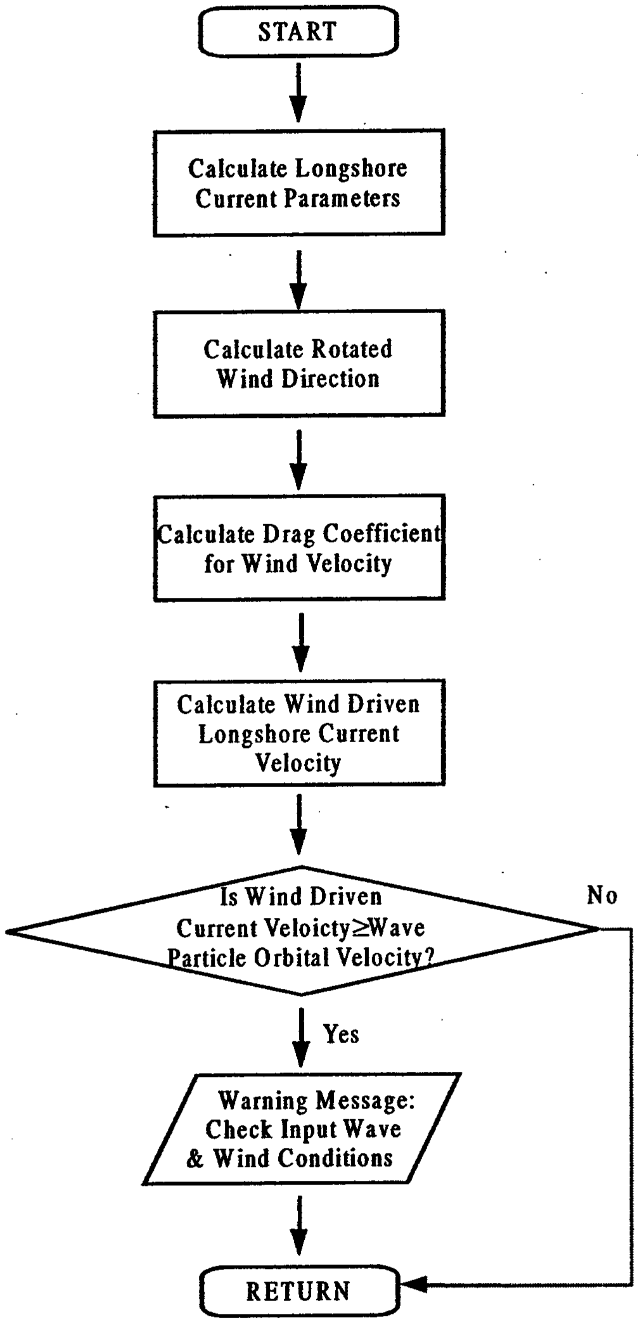
c4tmp	Real	Temporary Variable Used in Wind Velocity Vector Calculation
cd	Real	Coefficient of Drag Used in Wind Velocity Calculation
cf	Real	Coefficient of Friction for the Bottom
dwind	Real	Sign of Wind Vector (Positive or Negative)
m	Integer	Temporary Variable Used in Rotating Wind Angle
theta4	Real	Rotated Wind Direction
uorb	Real	Wave Particle Orbital Velocity
xn	Real	Eddy Viscosity Mixing Coefficient

Subroutines Called from S_COEFF ( ): None.

S_COEFF ( ) Called from Subroutines:

CALCSURF

Figure 49. Subroutine S_COEFF Flowchart



5.49 Subroutine S_NOSURF

Subroutine Call:

S_NOSURF (hsig, surf)

Summary:

Subroutine S_NOSURF is called to determine if local conditions are significant enough to proceed with surf zone calculations. The minimum condition for continuation is that the significant wave height calculated from the directional wave spectrum must be greater than 0.15 m.

Input Variables:

hsig	Real	Significant Wave Height

Output Variables:

surf	Logical	Flag to Indicate Low or No Surf Conditions (True or False)

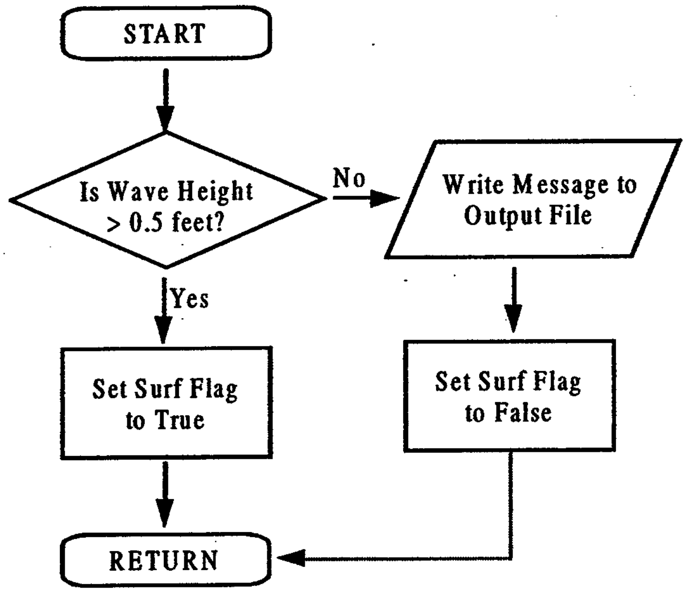
Local Variables: None.

Subroutines Called from S_NOSURF ( ): None.

S_NOSURF ( ) Called from Subroutines:

CALCSURF
RAD_ST2

Figure 50. Subroutine S_NOSURF Flowchart



5.50 Subroutine S_TIDE

Subroutine Call:

S_TIDE (tide, ydepth, nnn, dxy1, xx1, dxy, xshift)

Summary:

Subroutine S_TIDE adds the tidal elevation to each cross-shore point in the input depth profile.

Input Variables:

dxy1 (points)	Real	Corresponding Depths without Tide
nnn	Integer	Number of Points in Input Depth Array
tide	Real	Tide Level
xx1 (points)	Real	Adjusted Cross-Shore Distances from Depth Profile
ydepth	Char*1	Usage of Input Depth (Yes/No)

Output Variables:

dxy (points)	Real	Adjusted Depths with Tide
xshift	Real	Offshore Distance

Local Variables:

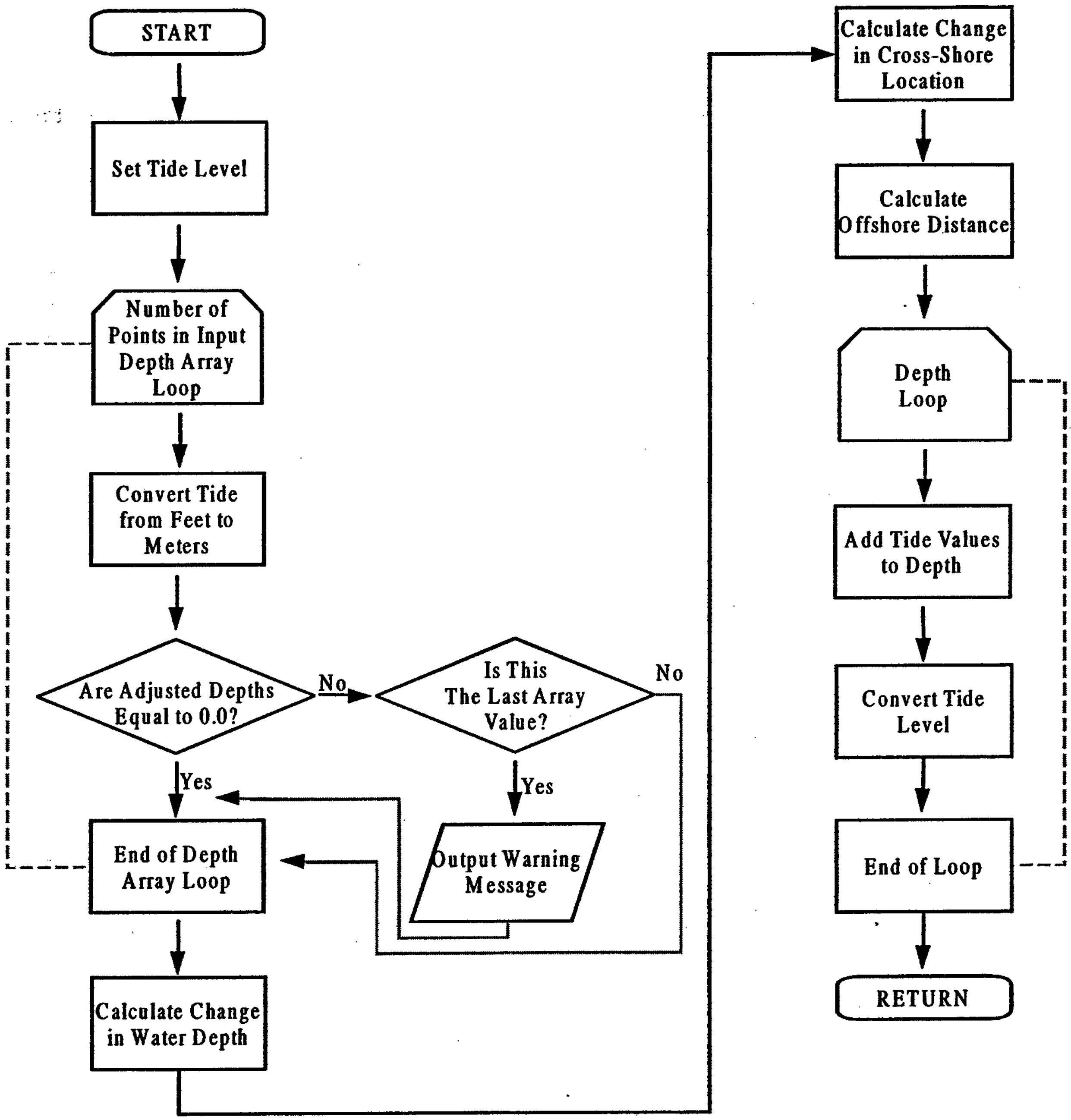
ddiff	Real	Change in Water Depth
n	Integer	Loop Counter
nn	Integer	Loop Counter
mm	Integer	Loop Counter
xdiff	Real	Change in Cross-Shore Location
ztide	Real	Tide Level

Subroutines Called from S_TIDE ( ): None.

S_TIDE ( ) Called from Subroutines:

CALCSURF

Figure 51. Subroutine S_TIDE Flowchart



5.51 Subroutine SEAFIT

Subroutine Call:

SEAFIT (hsig, per, dir, ifreq, idirec, freq1, freq2, xfrom, esowm)

Summary:

Subroutine SEAFIT calculates a directional wave spectrum from an input wave height and wave period using a Pierson-Moskowitz spectrum representation and a cosine to the fourth directional spreading function. The modified Pierson-Moskowitz equation (from Pierson and Moskowitz, 1964)

$$E(f) = a\, g^2\, w^{-5}\, e^{[-b(w_o/w)^4]}$$

provides wave energy at each frequency from the following equation:
where :

$$w = 2\pi f$$

in which f is the wave frequency in Hertz, g is gravity, and U is the wind speed in meters per second measured at 19.5 m above the sea surface. The spectrum $E(f)$ is a vector of spectral densities and it is

$$a = 0.0081$$

$$b = 0.74$$

$$w_o = \frac{g}{U}$$

assumed that each density is integrated from the lower limit of the frequency bin to the upper limit of the frequency bin.

Input Variables:

dir	Real	Wave Direction
freq1 (freqNum)	Real	Beginning Frequency Bin Value
freq2 (freqNum)	Real	Ending Frequency Bin Value
hsig	Real	Significant Wave Height
idirec	Integer	Number of Direction Bins in Input Spectrum

ifreq	Integer	Number of Frequencies in Input Spectrum
per	Real	Peak Period of Directional Wave Spectrum
xfrom (dirNum)	Real	Direction Array, Direction Wave Energy Comes From

Output Variables:

esowm (dirNum,freqNum)	Real	Directional Wave Spectrum

Local Variables:

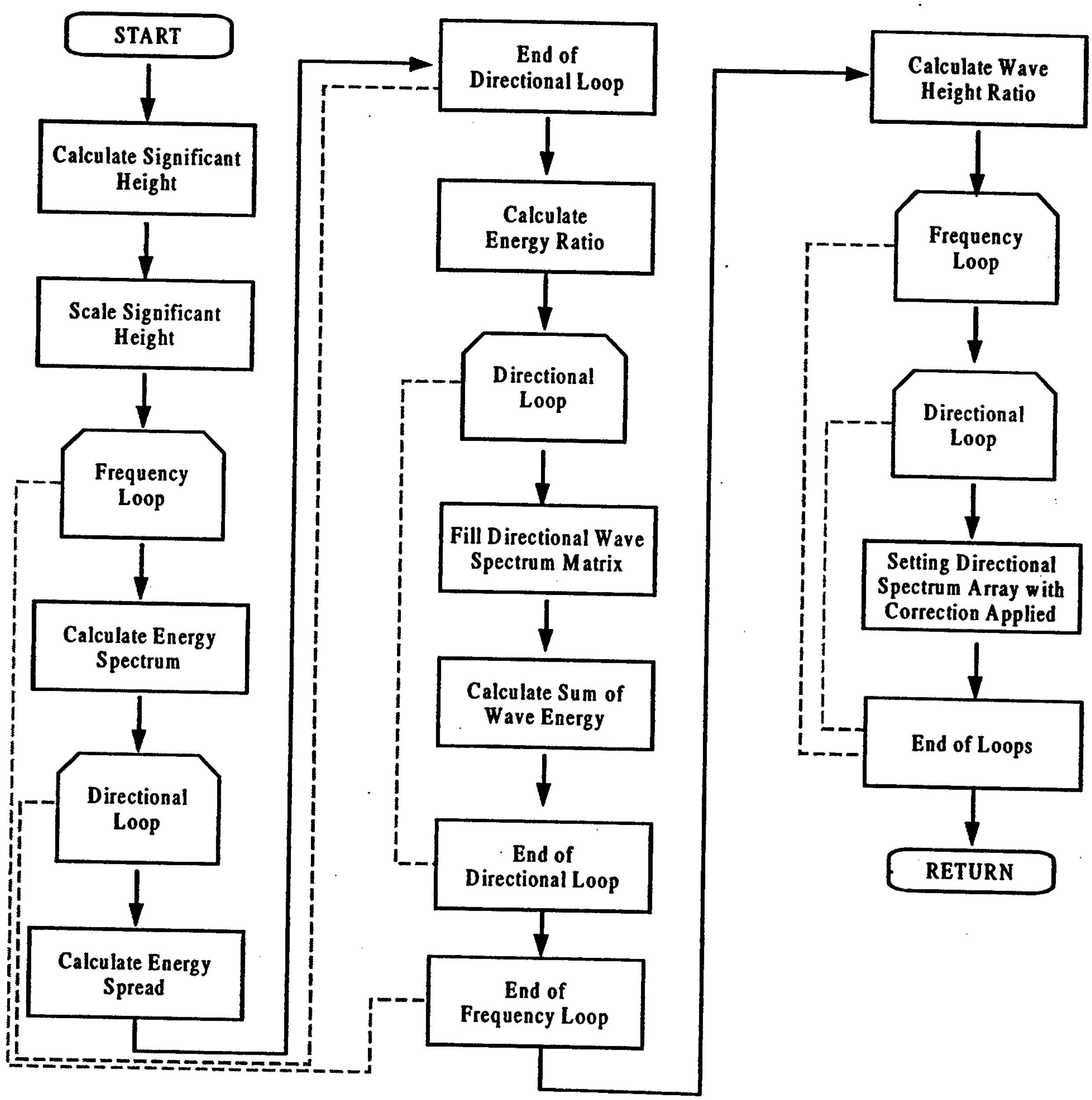
ang	Real	Temporary Wave Angle
b	Real	Constant = 0.74
const	Real	Variable in Pierson-Moskowitz Equation
e	Real	Variable in Pierson-Moskowitz Equation
enew	Real	Variable in Pierson-Moskowitz Equation
gu	Real	Variable in Pierson-Moskowitz Equation
hs	Real	Set to Significant Wave Height
hsl	Real	Set to Significant Wave Height
idir	Integer	Direction Loop Counter
ifrq	Integer	Frequency Loop Counter
ipm	Integer	Set to 1
ratio	Real	Set to 1.0
sprd	Real	Directional Spreading Factor
sum1	Real	Temporary Wave Energy Variable
sum2	Real	Temporary Wave Energy Variable
temp	Real	Variable in Pierson-Moskowitz Equation
theta	Real	Wave Angle
val1	Real	Variable in Pierson-Moskowitz Equation
val2	Real	Variable in Pierson-Moskowitz Equation
w1	Real	Wave Frequency at Beginning of Bin
w2	Real	Wave Frequency at End of Bin

Subroutines Called from SEAFIT ( ): None.

SEAFIT ( ) Called from Subroutines:

WAVEFIT

Figure 52. Subroutine SEAFIT Flowchart



5.52 Subroutine SETUP

Subroutine Call:

SETUP (pkfreq, d1, d2, hrms1, hrms2, eta1, kinit1, eta2)

Summary:

Subroutine SETUP calculates the change in the nearshore mean water level caused by the onshore flux of momentum or the shore-directed Radiation Stress. The presence of waves causes a change in the total water depth, which is defined by the still water level plus the wave-induced set-up.

Input Variables:

d1	Real	Corresponding Depth
d2	Real	Next Corresponding Depth
eta1	Real	Wave Induced Setup at Present Location
hrms1	Real	Root Mean Square Wave Height
hrms2	Real	Wave Height at next Onshore Grid Location
kinit1	Real	Wave Number
pkfreq	Real	Peak Frequency at the Center of the Frequency Band

Output Variables:

eta2	Real	Wave Induced Setup at New Location

Local Variables:

avg_depth	Real	Averaged Depth
convrg	Logical	Set to False
e1	Real	Total Average Energy for Offshore Wave
e2	Real	Total Average Energy for Wave Shoaled and Refracted Toward the Shore
en1	Real	Linear Wave Theory Ratio of Group Velocity to Wave Celerity
en2	Real	Linear Wave Theory Ratio of Group Velocity to Wave Celerity
eta_new	Real	Wave Induced Setup Estimated at New Location
i	Integer	Counter
k1	Real	First Wave Number Estimate
k2	Real	Second Wave Number Estimate
percent_diff	Real	Convergence Check
sxx1	Real	Cross-Shore Directed Radiation Stress
sxx2	Real	Cross-Shore Directed Radiation Stress
tol	Real	Convergence Tolerance

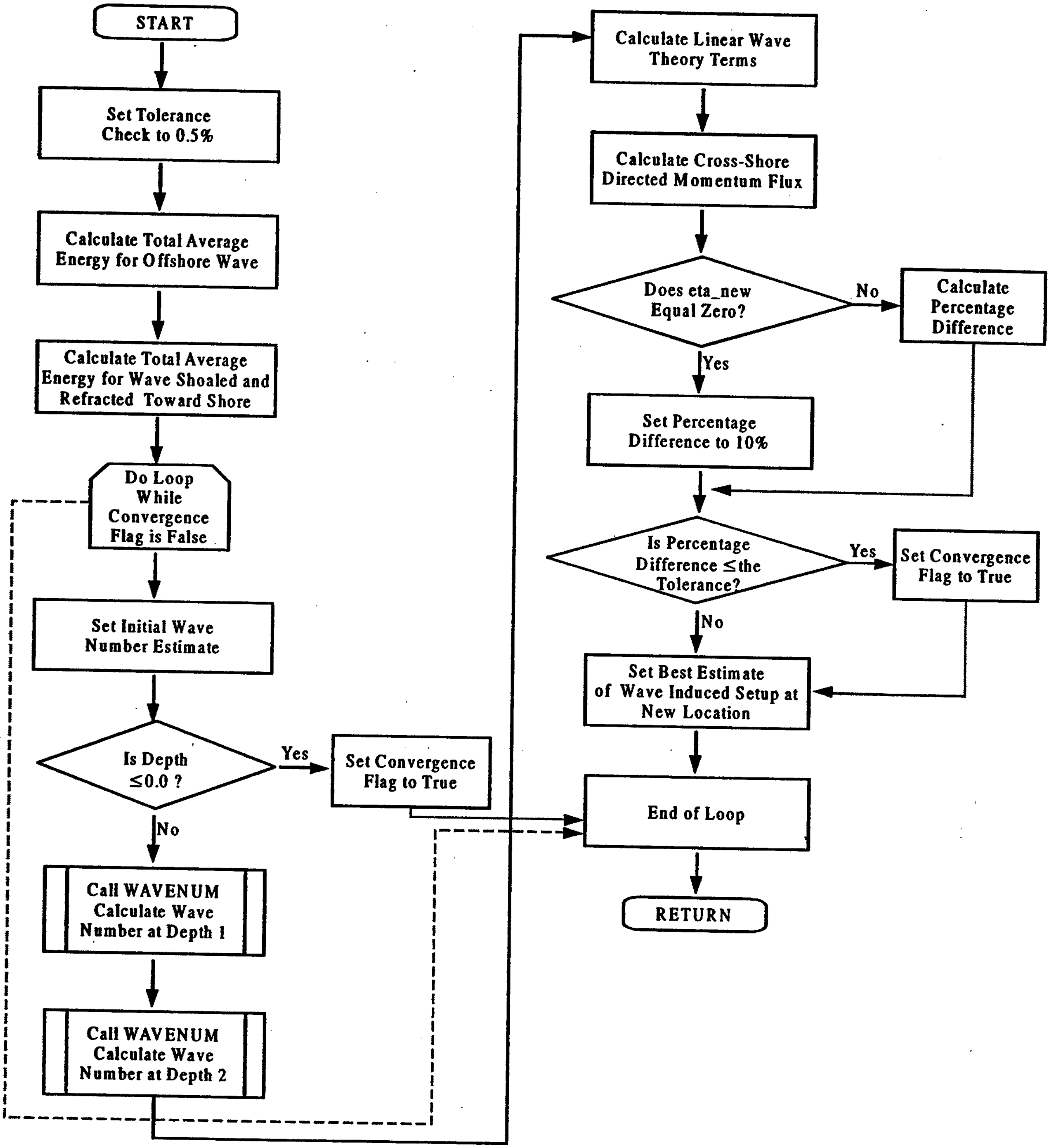
Subroutines Called from SETUP ( ):

WAVENUM

SETUP ( ) Called from Subroutines:

MAIN_WAV

Figure 53. Subroutine SETUP Flowchart



5.53 Subroutine SHORTOUT

Subroutine Call:

SHORTOUT (wdir, wspd, j, iimax, dxy, xtemp, sum1, k, h1max, h2max, per, pct, theta1, vmax, vmin, width, igamma, b1, rk, htemp, wid_ii, jgamma, alfa, bravo, chrlie, echo, foxtrt, golf1, golf2, ihtl1, ihtl2)

Summary:

Subroutine SHORTOUT defines the forecasting output variables.

Input Variables:

b1 (points)	Real	Bottom Slope Array
dxy (points)	Real	Corresponding Depths with Tide
h1max	Real	Largest Significant Wave Height in the Surf Zone
h2max	Real	Largest Maximum Wave Height in the Surf Zone
htemp (points)	Real	Temporary Variable for Significant Wave Height Values
igamma	Integer	Beach Orientation Rotated 90 Degrees from Original Heading Toward Beach
iimax	Integer	Number of Calculation Locations
j	Integer	Pre-tidal Depth or Still Water Level
k	Integer	Temporary Variable for Significant Wave Height
pct(4)	Real	Percentage Breaker Array
per	Real	Peak Period of Directional Wave Spectrum
rk (points, 4)	Real	Matrix of Percentage Breakers and Type of Breakers
sum1	Real	Sum of Wave Length in the Surf Zone
theta1	Real	Wave Angle at Input Starting Depth
vmax	Real	Maximum Positive Longshore Current Velocity
vmin	Real	Maximum Negative Longshore Current Velocity
wdir	Real	Input Wind Direction - Compass Heading Wind is Blowing From
wid_ii	Integer	Surf Zone Width Array Index
width	Real	Surf Zone Width
wspd	Real	Input Wind Speed
xtemp (points)	Real	Temporary Variable for Cross-Shore Values

Output Variables:

alfa	Real	Significant Breaker Height
bravo	Real	Maximum Breaker Height
chrlie	Real	Dominant Breaker Period
echo	Real	Breaker Angle
foxtrt	Real	Longshore Current Speed and Direction
golf1	Real	Number of Surf Lines
golf2	Real	Surf Zone Width
ihtl1	Real	Wind Speed
ihtl2	Real	Wind Direction
jgamma	Integer	Temporary Variable Set to Beach Orientation

Local Variables:

i1	Integer	Temporary Array
i2	Integer	Temporary Array
temp1	Real	Temporary Variable for Longshore Current Maximum Calculation
temp2	Real	Temporary Variable for Longshore Current Minimum Calculation
xlen	Real	Average Wave Length in Surf Zone

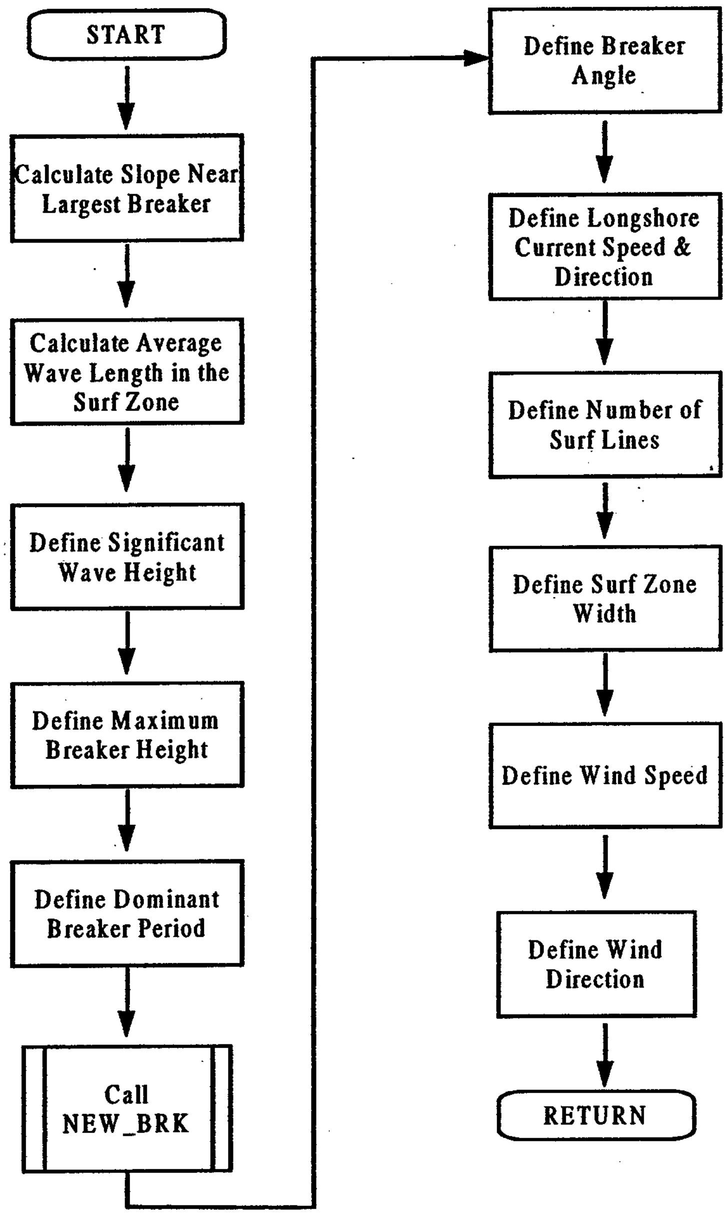
Subroutines Called from SHORTOUT( ):

NEW_BRK

SHORTOUT ( ) Called from Subroutines:

CALCSURF

Figure 54. Subroutine SHORTOUT Flowchart



5.54 Subroutine SLF_STRT

Subroutine Call:

SLF_STRT (theta, xdelt_gr, hrms, per, fqz, fqd, xx1, dxy, nnn, cg, hrms, xk, j_ii, l0, theta0, surf)

Summary:

Subroutine SLF_STRT shoals and refracts waves from the farthest offshore point to the shoreward point where the percentage of breaking exceeds the surf zone criteria of five percent (5%). If the five percent (5%) threshold is not exceeded, execution halts.

Input Variables:

b	Real	Empirical Factor in Wave Breaking Model
Cg	Real	Wave Group Velocity
dxy (points)	Real	Corresponding Depths with Tide
fqd	Real	Peak Frequency at the Center of the Frequency Band
fqz	Real	Zero Crossing Frequency
hrms	Real	Root Mean Square Wave Height
nnn	Integer	Number of Points in Input Depth Array
per	Real	Peak Period of Directional Wave Spectrum
self_st	Char*1	Self Staring Option (Yes or No)
theta	Real	Radiation Stress Angle
xdelt_gr	Real	Self-Adjusting Cross-Shore Grid Step
xk	Real	Wave Number

Output Variables:

Cg	Real	Wave Group Velocity
hrms	Real	Root Mean Square Wave Height
j_ii	Integer	Index where Wave Probabilities Exceed Threshold
l0	Real	Wave Length Offshore Location
surf	Logical	Index Where Percentage of Breakers Is Exceeded - Start of Surf Zone
theta0	Real	Wave Angle at Grid Offshore Location
xk	Real	Wave Number

Local Variables:

beta	Real	Bottom Slope
cg2	Real	Group Velocity
convg	Real	Convergence Flag (True or False)
dp	Real	Offshore Water Depth
eb	Real	Dissipation Term
hrms2	Real	Root Mean Square Wave Height
ii	Integer	Array Index
l	Real	Wave Length
p (4)	Real	Breaker Percentage Array
rhs	Real	Right Hand Side of Energy Equation
roller	Logical	Roller Option Flag (True or False)
rstart	Real	Percent Breaking Wave Criteria
xk0	Real	Offshore Wave Number

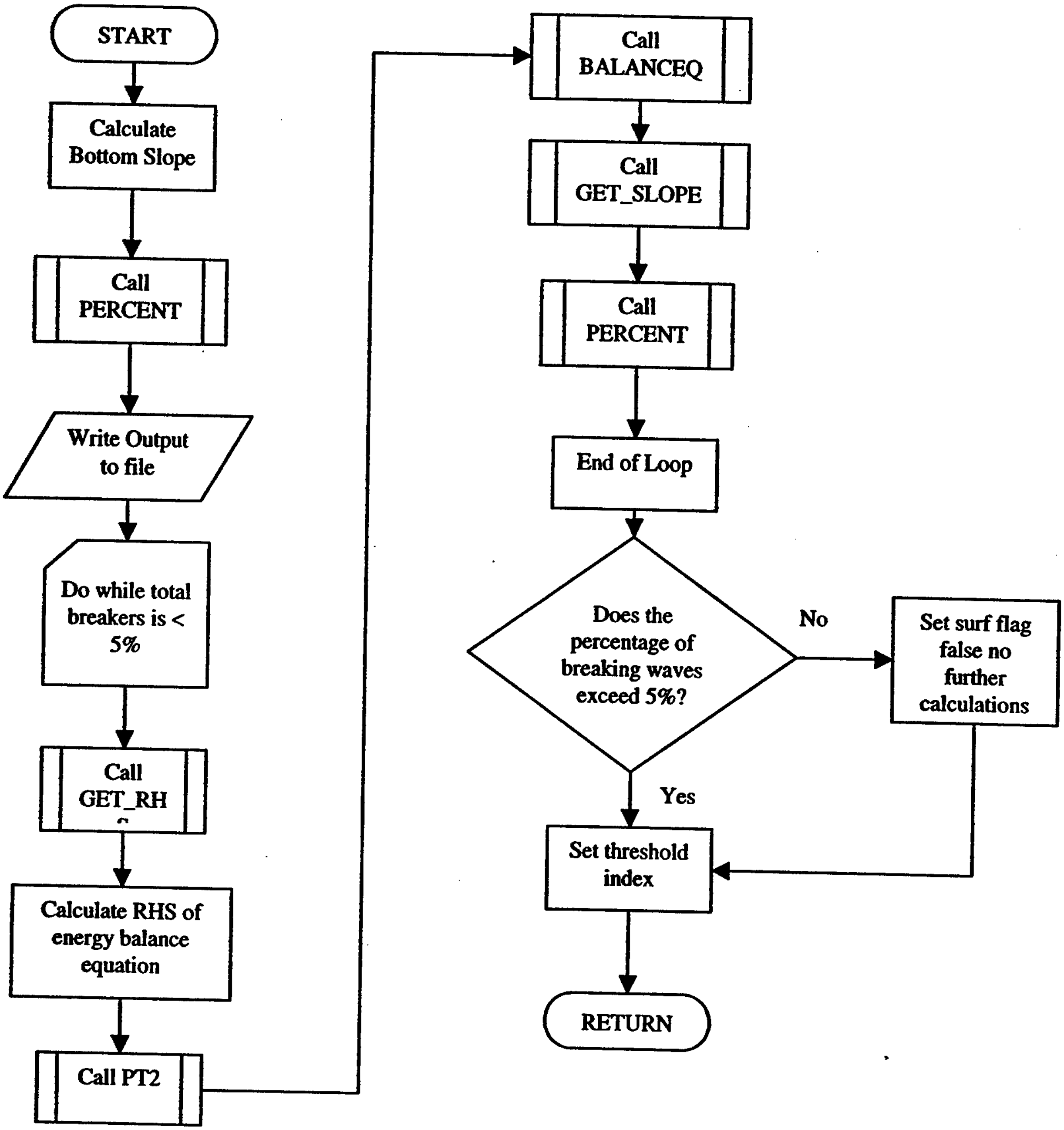
Subroutines Called from SLF_STRT ( ):

BALANCEQ
GET_RHS
PERCENT
PT2

SLF_STRT ( ) Called from Subroutines:

MAIN_WAV

Figure 55. Subroutine SLF_STRT Flowchart



5.55 Subroutine SRFSETUP

Subroutine Call:

SRFSETUP (file_in, file_out, fracname, lndname, depname, iyear, imonth, iday, ihour, imin, gamma2, ydepth, slope, ydetail, xdelt, yrefrac, ystr, self_st, hsea, psea, dsea, hswell, pswell, dswell, wspd, wdir, tide, spefile, file_dat, file_tmp, spedepth, file_spc, spe_type)

Summary:

Subroutine SRFSETUP opens input and output files. Input variables are initialized using data from user-constructed input file. The format of the input file is outlined in Section 6.0.

Input Variables: None.

Output Variables:

depname	Char*40	Depth Profile File Name
dsea	Real	Input Direction for Sea Contribution
dstart	Real	Input Starting Depth
dswell	Real	Input Swell Direction for Internally Generated Spectrum
file_in	Char*40	Input File Name
file_out	Char*40	Output File Name
file_dat	Char*40	Output File Name
file_spc	Char*40	Shallow Water Wave Spectrum File Name
file_tmp	Char*40	Output File Name
fracname	Char*40	Wave Refraction File Name
gamma2	Real	Beach Orientation, Compass Heading Directly Toward Beach
gt_frg	Integer	Spectrum Type
hsea	Real	Input Significant Wave Height for Sea Contribution to Pierson Moskowitz Spectrum
hswell	Real	Input Significant Wave Height for Internally Generated Spectrum
iday	Integer	Input Day
ihour	Integer	Input Hour
imin	Integer	Input Minute
imonth	Integer	Input Month
iyear	Integer	Input Year
lndname	Char*40	Input Landing Zone Name
psea	Real	Input Wave Period for Sea Contribution to Internally Generated Spectrum
pswell	Real	Input Swell Period for Internally Generated Spectrum

self_st	Char*1	Self Start Flag (Yes or No)
slope	Real	Bottom Slope
spedepth	Real	Depth at Offshore Wave Spectrum
spefile	Char*40	Selected Wave Spectrum File Name
spe_type	Integer	0 if spefile is not blank, 1 for blank
tide	Real	Input Tide Level
wdir	Real	Input Wind Direction, Compass Heading Wind Blows From
wspd	Real	Input Wind Speed
xdelt	Real	Surf Zone Output Interval
ydepth	Char*1	Input Depth Profile Used? (Yes or No)
ydetail	Char*1	Detailed Output? (Yes or No)
yrefrac	Char*1	Is Refraction Considered in Analysis? (Yes or No)
ystr	Char*1	Is Straight Coast Refraction Used? (Yes or No)

Local Variables:

dum1	Char*80	Title Line
fend	Integer	File Name Prefix Used for Building File Names
file_dat	Char*20	Additional Output File Name
i	Integer	Loop Counter
iopen	Integer	I/O Status Number
j	Integer	Loop Counter

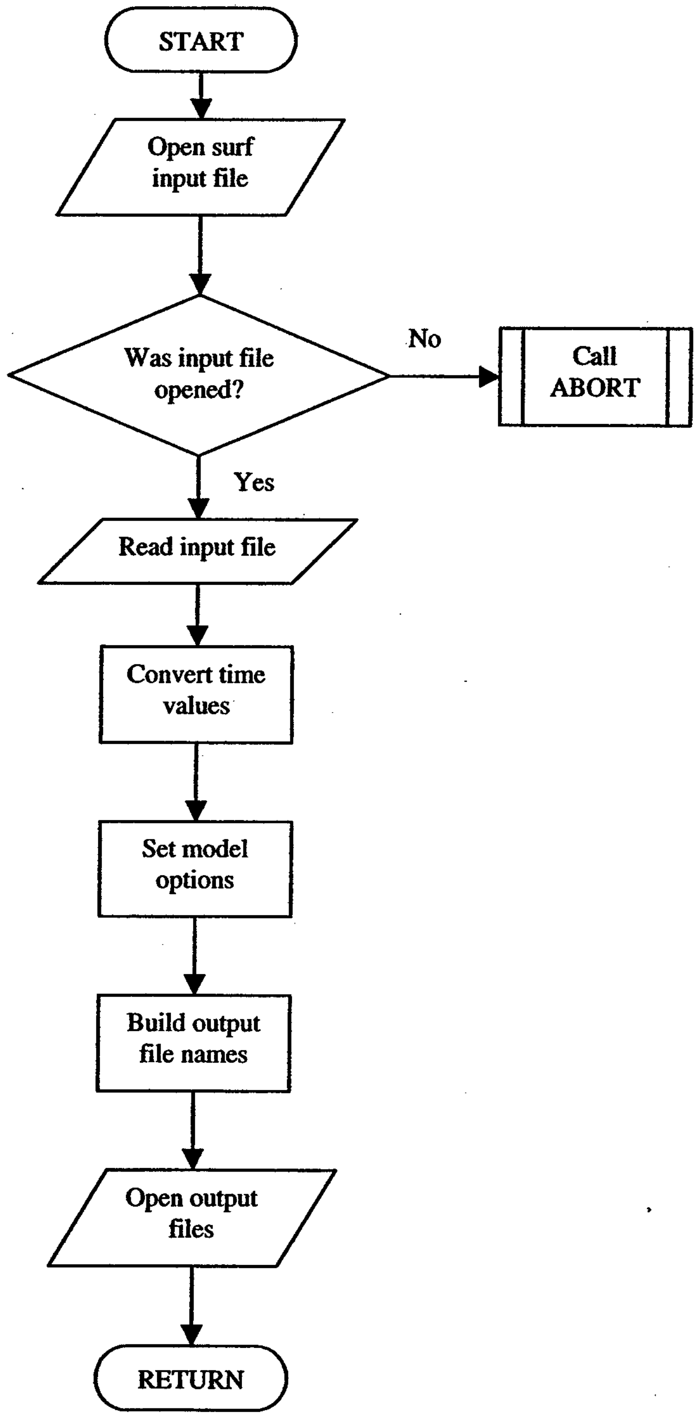
Subroutines Called from SRFSETUP ( ):

ABORT

SRFSETUP ( ) Called from Subroutines:

SURF

Figure 56. Subroutine SRFSETUP Flowchart



5.56 Subroutine STRFRAC

Subroutine Call:

STRFRAC (dstart, ifreq, freq, igamma, idirec, xfrom, spedepth, xcoeff, xtheta)

Summary:

Subroutine STRFRAC calculates wave angle refraction coefficients and combined shoaling and refraction coefficients to propagate wave energy into shallow water.

Input Variables:

dstart	Real	Input Starting Depth
freq (freqNum)	Real	Input Wave Spectrum Center Frequencies
idirec	Integer	Number of Direction Bins in Input Spectrum
ifreq	Integer	Number of Frequency Bins in Input Spectrum
igamma	Integer	Beach Orientation Rotated 90 Degrees from Original Heading Toward Beach
xfrom (dirNum)	Real	Direction Array

Output Variables:

xcoeff (dirNum,freqNum)	Real	Wave Height Refraction Coefficients
xtheta (dirNum,freqNum)	Real	Wave Angle Refraction Coefficients

Local Variables:

arg1	Real	Shallow Water Angle (1) - Temporary
direc	Real	Temporary Direction Angle
frd	Real	Wave Frequency
idir	Integer	Direction Loop Counter
ifrq	Integer	Frequency Loop Counter
m	Integer	Temporary Wave Angle
noprint	Real	Wave Component Direction
shoal	Real	Temporary Shoaling Coefficient
shoal2	Real	Temporary Shoaling Coefficient at Input Starting Depth
thetad	Real	Temporary Wave Angle Variable
thetas2	Real	Temporary Wave Angle Variable
xkd	Real	Temporary Wave Number Variable
xk2	Real	Temporary Wave Number Variable

xks2	Real	Temporary Wave Number at Input Starting Depth
xksd2	Real	Wave Number at Input Starting Depth

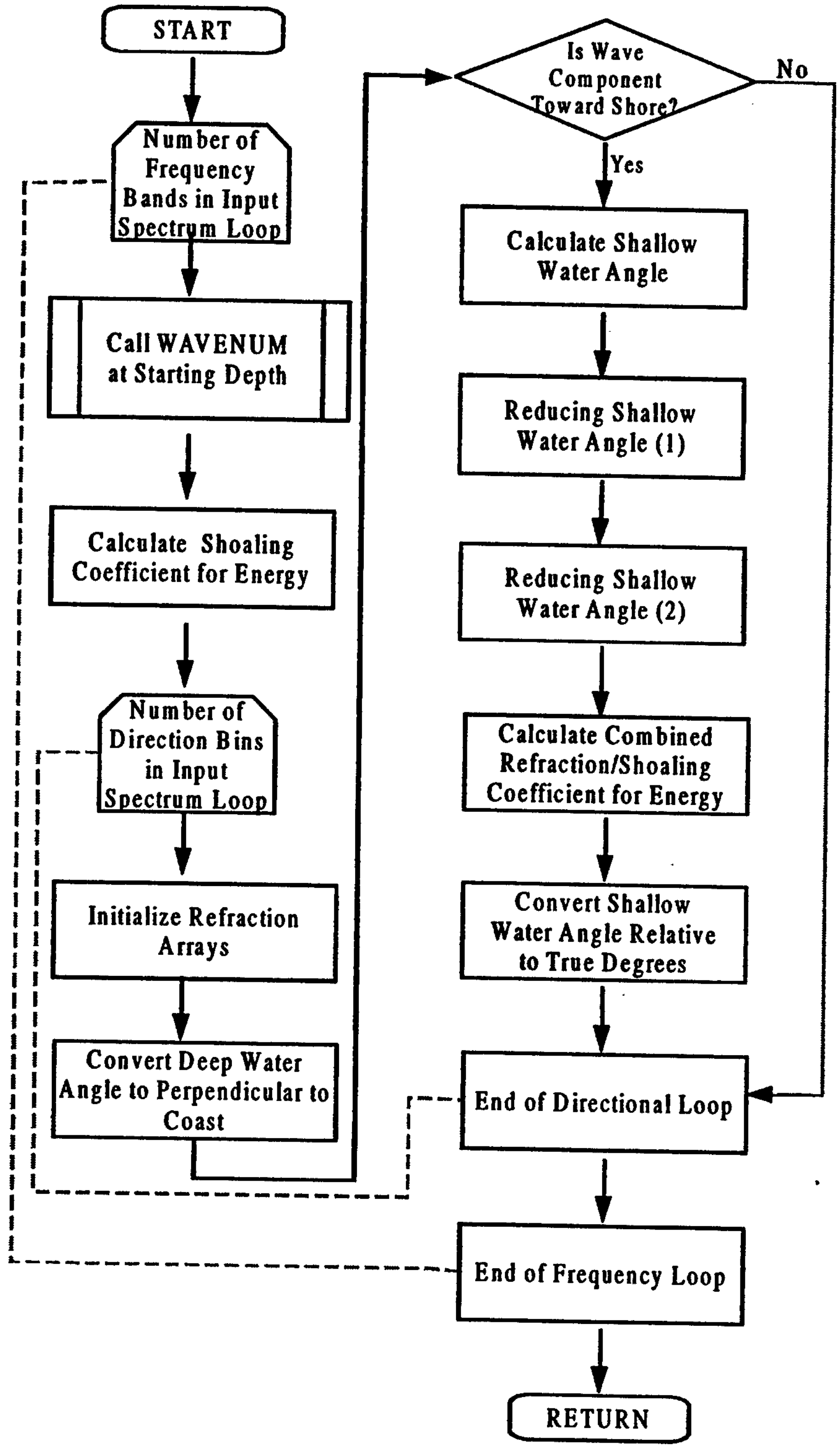
Subroutines Called from STRFRAC ( ):

WAVENUM

STRFRAC ( ) Called from Subroutines:

SURF

Figure 57. Subroutine STRFRAC Flowchart



5.57 Subroutine SUMMARY

Subroutine Call:

SUMMARY (spedepth, dstart, tide, wspd, wdir, xdelt, yrefrac, ystr, depname, file_out, fracname, lndname, ydepth, ydetail, gamma2, slope, hsea, psea, dsea, hswell, pswell, dswell, spectra, spefile, spe_type, file_tmp)

Summary:

Subroutine SUMMARY summarizes the input information read to the output file for documentation and forecaster verification.

Input Variables:

depname	Char*40	Depth Profile File Name
dsea	Real	Input Direction for Sea Contribution
dstart	Real	Input Starting Depth
dswell	Real	Input Swell Direction for Internally Generated Spectrum
file_out	Char*40	Output File Name *.out
file_tmp	Char*40	Tempary Output File Name *.tmp
fracname	Char*40	Wave Refraction File Name
gamma2	Real	Beach Orientation, Compass Heading Directly Toward Beach
hsea	Real	Input Significant Wave Height for Sea Contribution to Internally Generated Spectrum
hswell	Real	Input Significant Wave Height to Internally Generated Spectrum
lndname	Char*40	Input Landing Zone Name
psea	Real	Input Wave Period for Sea Contribution to Internally Generated Spectrum
pswell	Real	Input Swell Period for Internally Generated Spectrum
slope	Real	Bottom Slope for a Constructed Depth Profile
spectra	Logical	Does Input Spectrum Exist? (True or False)
spedepth	Real	Wave Input Depth
spefile	Char*40	Selected Wave Spectrum File Name
spe_type	Integer	0 if spefile is not blank, 1 for blank
tide	Real	Input Tide Level
wdir	Real	Input Wind Direction Compass Heading Wind Blows From
wspd	Real	Input Wind Speed
xdelt	Real	Surf Zone Output Interval
ydepth	Char*1	Input Depth Profile Used? (Yes or No)
ydetail	Char*1	Detailed Output? (Yes or No)
yrefrac	Char*1	Is Refraction Considered in Analysis?

		(Yes or No)
ystr	Char*1	Is Straight Coast Refraction Used? (Yes or No)

Output Variables: None.

Local Variables:

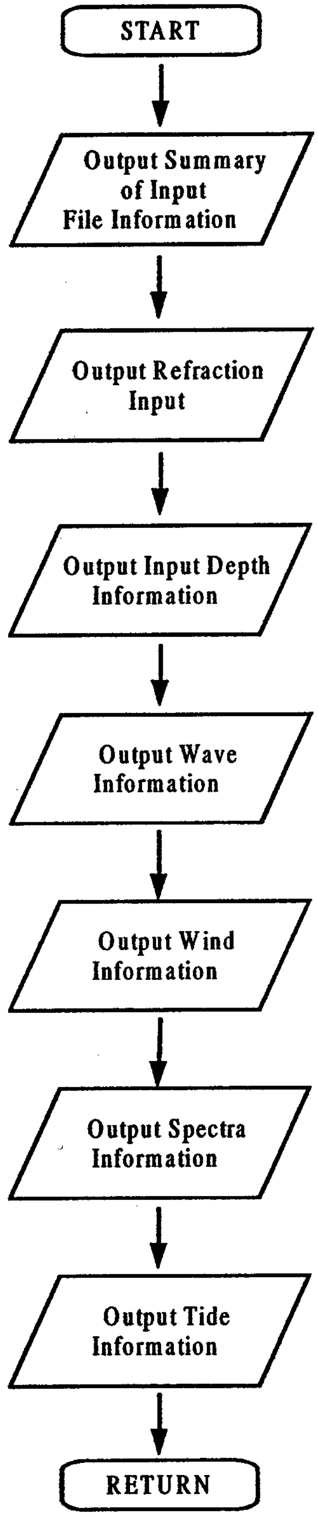
sediment	Char*40	Sediment Type

Subroutines Called from SUMMARY ( ): None.

SUMMARY ( ) Called from Subroutines:

SURF

Figure 58. Subroutine SUMMARY Flowchart



5.58 Subroutine SURFCAST

Subroutine Call:

SURFCAST (pct, depname, lndname, slope, ydepth, alfa, bravo, chrlie, echo, foxtrt, golf1, golf2, ihtl1, ihtl2)

Summary:

Subroutine SURFCAST reads input variables and provides a short format summary of Navy specified parameters. The subroutine also examines longshore current direction and selects the dominant breaker type.

Input Variables:

alfa	Real	Significant Breaker Height
bravo	Real	Maximum Breaker Height
chrlie	Real	Dominant Breaker Period
depname	Char*40	Depth Profile File Name
echo	Real	Breaker Angle
foxtrt	Real	Longshore Current Speed and Direction
golf1	Real	Number of Surf Lines
golf2	Real	Surf Zone Width
ihtl1	Real	Wind Speed Coded Surf Forecast Value
ihtl2	Real	Wind Direction
lndname	Char*40	Input Landing Zone Name
pct (4)	Real	Percent of Different Breaker Types: pct (1) = Spilling pct (2) = Plunging pct (3) = Surging pct (4) = Total
slope	Real	Bottom Slope
ydepth	Char*1	Input Depth Profile Used? (Yes or No)

Output Variables: None.

Local Variables:

foxtmp	Real	Longshore Current Where the Sign Indicates the Direction
i	Integer	Loop Counter Variable
jdelt	Integer	Difference If Any Between 100% and Sum of jp (4)
jp (4)	Integer	Temporary Variable Same as pct(4) Array

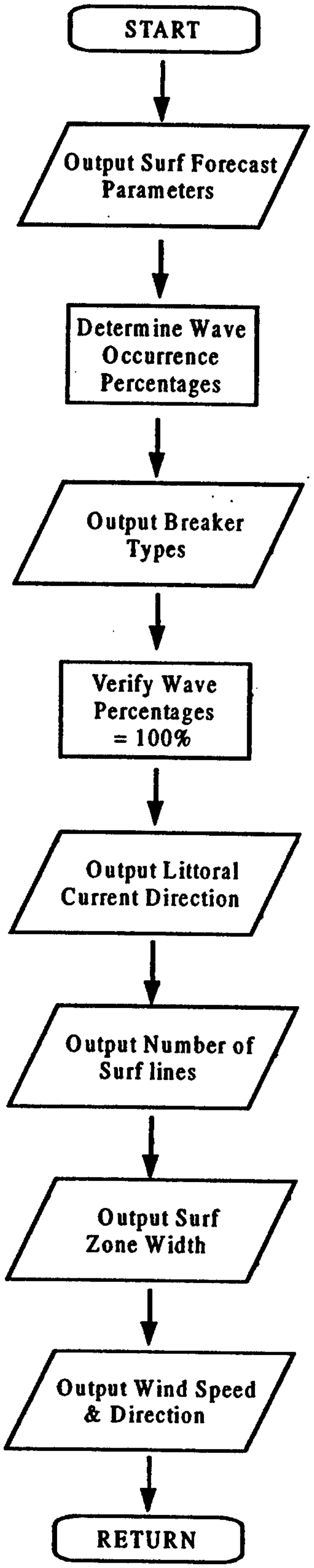
jsum	Integer	Check for Percentages Adding to 100%
maxp	Integer	Indicates Dominant Breaker Type
xmax	Real	Temporary Variable Used in Dominant Breaker Type Examination

Subroutines Called from SURFCAST ( ): None.

SURFCAST ( ) Called from Subroutines:

SURF

Figure 59. Subroutine SURFCAST Flowchart



5.59 Subroutine SWLFIT

Subroutine Call:

SWLFIT (hsig, per, dir, dangle, ifreq, idirec, period, esowm)

Summary:

Subroutine SWLFIT superimposes remotely generated swell wave energy onto the existing directional wave spectrum. The existing wave spectrum may be zero or it may contain locally generated sea waves already added by the subroutine SEAFIT.

Input Variables:

dangle	Real	Angle between Directional Bins
dir	Real	Input Swell Direction for Internally Generated Spectrum
hsig	Real	Significant Wave Height
idirec	Integer	Number of Direction Bins in Input Spectrum
ifreq	Integer	Number of Frequency Bins in Input Spectrum
per	Real	Peak Period of Directional Wave Spectrum
period (freqNum)	Real	Period Array (1 / Frequency)

Output Variables:

esowm (dirNum,freqNum)	Real	Directional Wave Spectrum

Local Variables:

d1	Real	Temporary Variable for Distributing Wave Energy
d2	Real	Temporary Variable for Distributing Wave Energy
d3	Real	Temporary Variable for Distributing Wave Energy
delt	Real	Temporary Variable for Distributing Wave Energy
diff	Real	Difference between Maximum Wave Period and Array Value of Wave Period
dmin	Real	Set to 1000.0
energy	Real	Swell Energy
ifrq	Integer	Frequency Loop Counter
jdir	Integer	Swell Direction
jdir1	Integer	Direction Bin Index Number
jdir3	Integer	Direction Bin Index Number

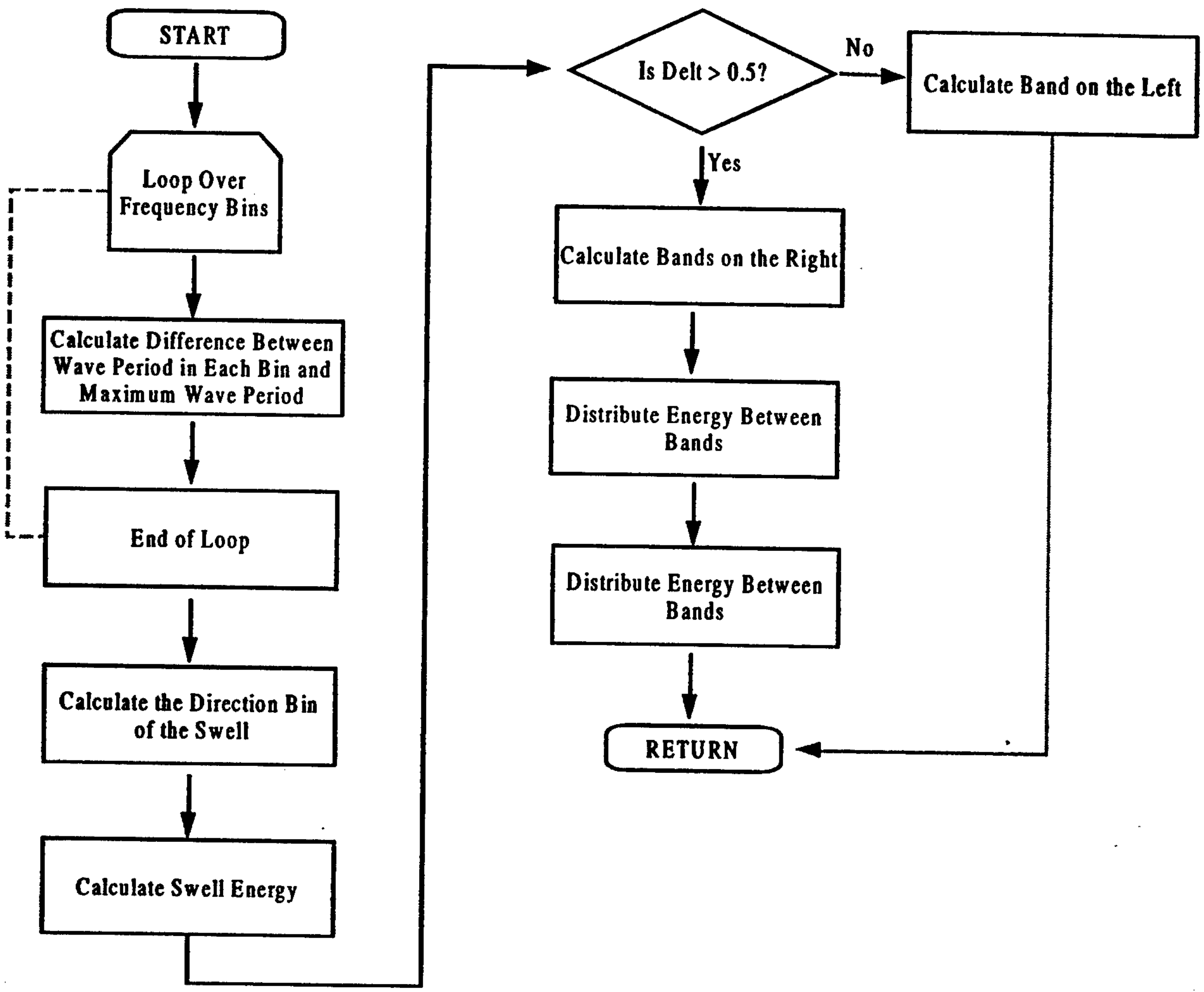
jfreq	Integer	Directional Wave Spectrum Wave Number
xdir	Real	Wave Direction

Subroutines Called from SWLFIT ( ): None.

SWLFIT ( ) Called from Subroutines:

WAVEFIT

Figure 60. Subroutine SWLFIT Flowchart



5.60 Subroutine WAVEFIT

Subroutine Call:

WAVEFIT (ifreq, idirec, dangle, hsea, psea, dsea, hswell, pswell, dswell, freq1, freq2, xfrom, period, esowm, ehsig)

Summary:

Subroutine WAVEFIT initializes the internally generated directional wave spectrum to zero and calls subroutines SEAFIT and SWLFIT to fill the matrix.

Input Variables:

dangle	Real	Angle Between Directional Bins
dsea	Real	Input Direction for Sea Contribution to Internally Generated Wave Spectrum
dswell	Real	Input Swell Direction for Internally Generated Spectrum
freq1 (freqNum)	Real	Beginning Frequency Bin Value
freq2 (freqNum)	Real	Ending Frequency Bin Value
hsea	Real	Input Significant Wave Height for Sea Contribution to Internally Generated Wave Spectrum
hswell	Real	Input Significant Wave Height to Internally Generated Spectrum
idirec	Integer	Number of Direction Bins in Input Spectrum
ifreq	Integer	Number of Frequencies in Input Spectrum
period (freqNum)	Real	Period Array (1/Frequency)
psea	Real	Input Wave Period for Sea Contribution
pswell	Real	Input Swell Period for Internally Generated Spectrum
xfrom (dirNum)	Real	Direction Array, Direction Wave Energy Comes From

Output Variables:

ehsig	Real	Significant Wave Height from Directional Spectrum
esowm (dirNum,freqNum)	Real	Directional Wave Spectrum

Local Variables:

idir	Integer	Direction Loop Counter
ifrq	Integer	Frequency Loop Counter

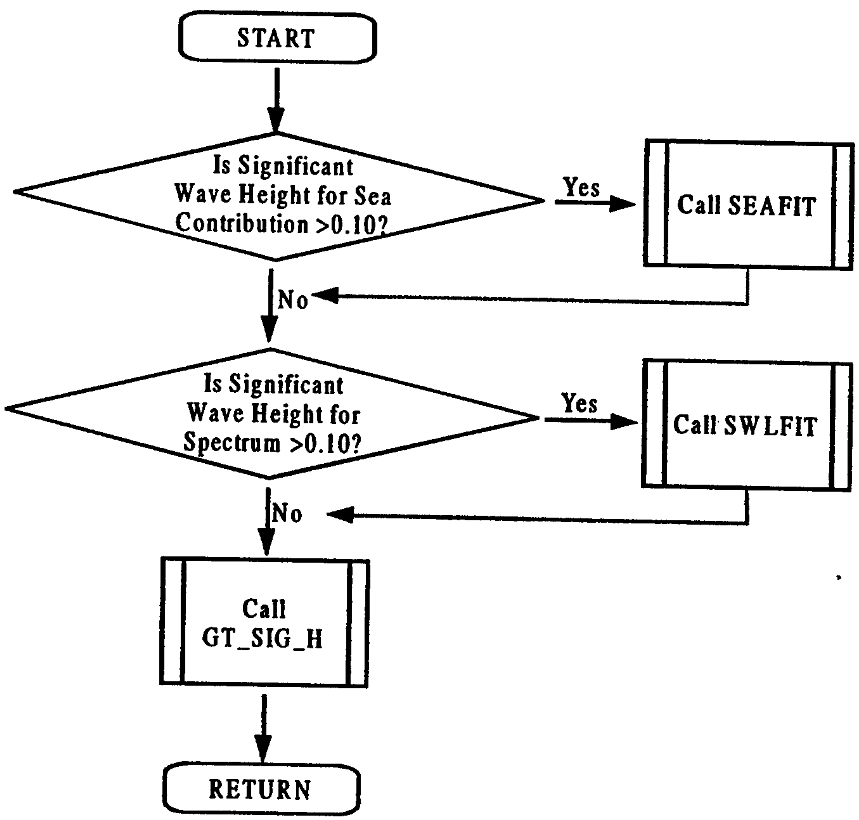
Subroutines Called from WAVEFIT ( ):

GT_SIG_H
SEAFIT
SWLFIT

WAVEFIT ( ) Called from Subroutines:

GENSPEC

Figure 61. Subroutine WAVEFIT Flowchart



5.61 Subroutine WAVENUM

Subroutine Call:

WAVENUM (fq, dp, xk)

Summary:

The wave dispersion equation is solved for the wave number through numerical iteration. A relative change of less than .0005 is required and the maximum number of iterations is 150. If convergence is not obtained within 150 iterations, a shallow water approximation is employed.

Input Variables:

dp	Real	Offshore Water Depth
fq	Real	Wave Frequency

Output Variables:

xk	Real	Wave Number

Local Variables:

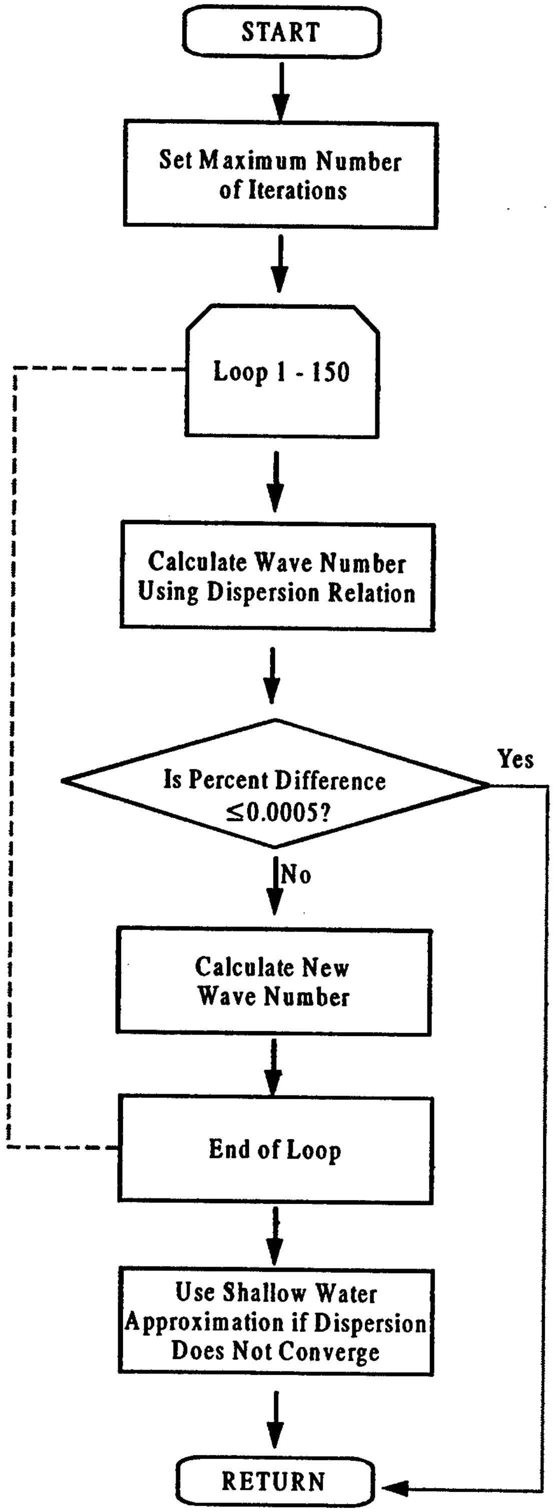
const	Real	Shallow Water Criteria Constant
diff	Real	Percent Difference between Wave Number Estimates
est	Real	Estimate of Wave Number
I	Integer	Loop Counter
it	Integer	Loop Limit - Set to 150

Subroutines Called from WAVENUM ( ): None.

WAVENUM ( ) Called from Subroutines:

INITLIZE
PT2
RAD_ST1
RAD_ST2
SETUP
STRFRAC

Figure 62. Subroutine WAVENUM Flowchart



5.62 Subroutine WEIGHTFN

Subroutine Call:

WEIGHTFN (dp, hrms, h, w_h)

Summary:

Subroutine WEIGHTFN calculates the weighting function used to describe the distribution of breaking waves across the surf zone.

Input Variables:

dp	Real	Offshore Water Depth
h	Real	Wave Height
hrms	Real	Root Mean Square Wave Height

Output Variables:

w_h	Real	Output Weighting Function

Local Variables:

m	Real	Multiplier
temp	Real	Weighting Function
tol	Real	Set to –700.0

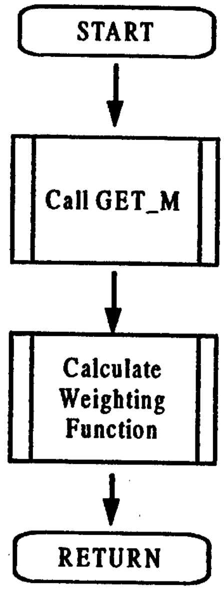
Subroutines Called from WEIGHTFN ( ):

GET_M

WEIGHTFN ( ) Called from Subroutines:

F2

Figure 63. Subroutine WEIGHTFN Flowchart



5.63 Subroutine ZONE1

Subroutine Call:

ZONE1 (j_ii, iimax, dxy, xtemp, htemp, ptemp, thetatemp, xktemp, v, distmax, vmax, vmin, thetamin, thetamax, sum1, width, j, k, h1max, h2max, wid_ii)

Summary:

Subroutine ZONE1 calculates the preliminary surf forecast values and surf zone parameters.

Input Variables:

distmax	Real	Farthest Distance Offshore
dxy (points)	Real	Pre-Tidal Depth or Still Water Level
htemp (points)	Real	Temporary Variable for Significant Wave Height Values
iimax	Integer	Number of Calculation Locations
j_ii	Integer	Index where Wave Probabilities Exceed Threshold
ptemp (points)	Real	Percentage of Breaking Waves and Breaker Types
v (points)	Real	Longshore Current
xktemp (points)	Real	Temporary Variable for Wave Number
xtemp (points)	Real	Temporary Variable for Cross-Shore Values

Output Variables:

h1max	Real	Maximum Significant Wave Height
h2max	Real	Maximum Wave Height
j	Integer	Array Index Where Maximum Significant Wave Height Occurs
k	Integer	Temporary Variable Number of Points in Cross-Shore Transect
suml	Real	Summation of Wave Lengths Across the Surf Zone
vmax	Real	Maximum Positive Longshore Current Velocity
vmin	Real	Maximum Negative Longshore Current Velocity
wid_ii	Integer	Array Index for X-value at Surf Zone Boundary
width	Real	Surf Zone Width

Local Variables:

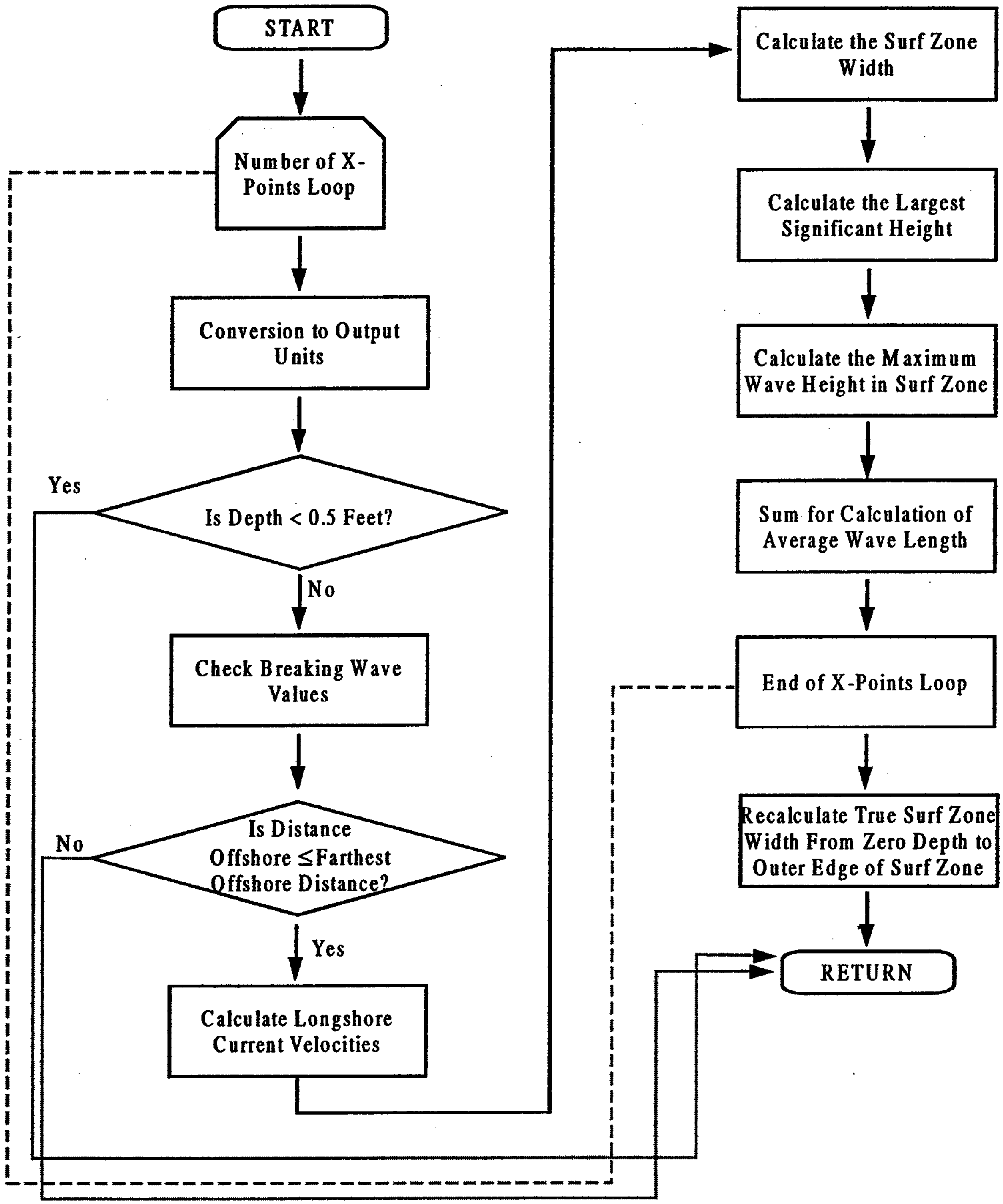
dp1	Real	Offshore Depth in Feet
hdep	Real	Limiting Breaking Depth
hmax	Real	Temporary Variable for Maximum Wave Height
hout1	Real	Temporary Variable for Significant Wave Height
hrms1	Real	Root Mean Square Wave Height
ii	Integer	Loop Index
ving1	Real	Longshore Current Velocity in Knots
wlen	Real	Wave Length
xoff1	Real	Distance Offshore

Subroutines Called from ZONE1 ( ): None.

ZONE1 ( ) Called from Subroutines:

CALCSURF

Figure 64. Subroutine ZONE1 Flowchart



5.64 Function F2

Function Call:

F2 (h, hrms, dp, p_flag)

Summary:

Function F2 evaluates the Rayleigh probability distribution function for a given wave height value, for a selected weighting function.

Input Variables:

dp	Real	Offshore Water Depth
h	Real	Wave Height
hrms	Real	Root Mean Square Wave Height
p_flag	Logical	Weighting Factor Flag (True or False)

Output Variables:

f2	Real	Weighted Rayleigh Distribution

Local Variables:

p_h	Real	Rayleigh Probability Distribution
temp	Real	Exponent Term in Rayleigh Distribution
tol	Real	Tolerance Value Set to -700.0
w_h	Real	Weighting Function

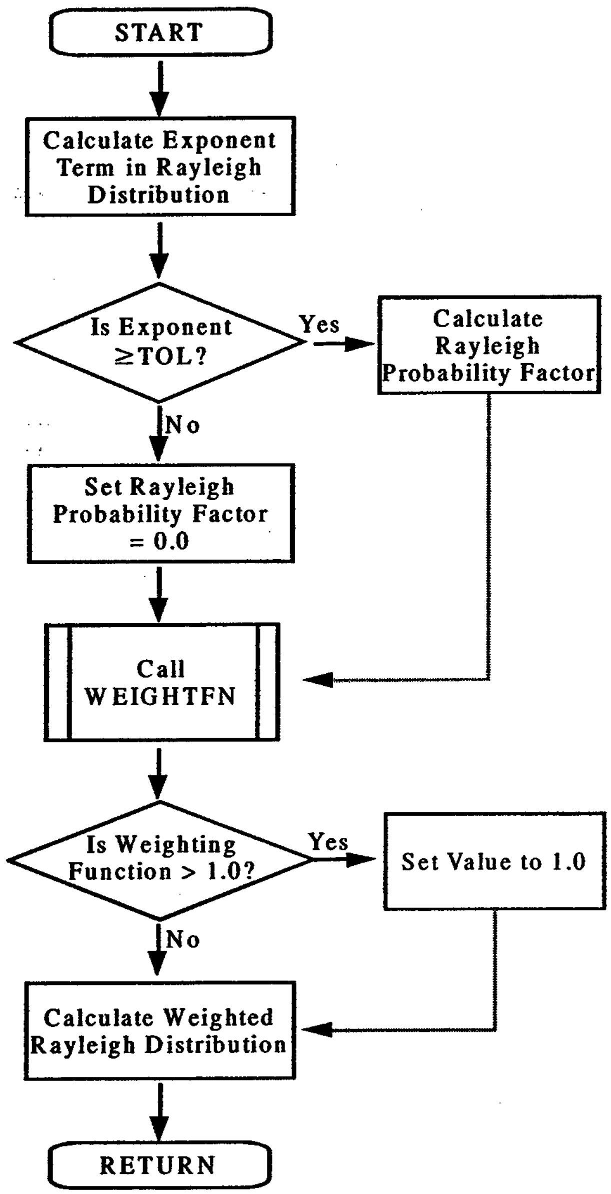
Subroutines Called from F2 ( ):

WEIGHTFN

F2 ( ) Called from Functions:

INTEGRAT

Figure 65. Function F2 Flowchart



5.65 Function F3

Function Call:

F3 (hrms, theta, Cg, dp, mean_freq, xk, roller)

Summary:

Function F3 returns values for the LHS of the energy equation.

Input Variables:

Cg	Real	Wave Group Velocity
dp	Real	Offshore Water Depth
hrms	Real	Root Mean Square Wave Height
mean_freq	Real	Directional Spectrum Value
roller	Logical	Roller Option Flag (True or False)
theta	Real	Wave Angle
xk	Real	Wave Number

Output Variables:

f3	Real	Total Energy

Local Variables:

e_roller	Real	Roller Contribution to the Energy Equation
e_wave	Real	Wave Contribution to the Energy Equation

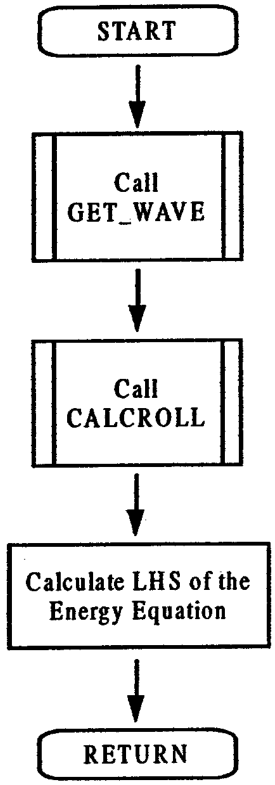
Subroutines Called from F3 ( ):

CALCROLL
GET_WAVE

F3 ( ) Called from Subroutines:

BALANCEQ

Figure 66. Function F3 Flowchart



5.66 Function INTEGRAT

Function Call:

INTEGRAT (xo, xn, hrms, dp, p_flag)

Summary:

Function INTEGRAT evaluates an integral numerically using the trapezoidal rule. Function {F2} is called to evaluate the integral at upper and lower limits. The function applies the trapezoidal integration method to estimate the wave height at a particular depth from a weighted distribution.

Input Variables:

dp	Real	Farthest Offshore Water Depth
hrms	Real	Root Mean Square Wave Height
p_flag	Logical	Weighting Factor Flag (True or False)
xn	Real	Upper Limit of Integration = 5 * hrms
xo	Real	Lower Limit of Integration = 0.0

Output Variables:

integrat	Real	Wave Height Distribution Calculated for a Specific Location

Local Variables:

delt	Real	Step Between Intervals
f_xn	Real	f(x) Evaluated at Upper Limit
f_xo	Real	f(x) Evaluated at Lower Limit
f2	Real	Wave Height Distribution Weighting Function
i	Integer	Loop Variable
numit	Integer	Set to 100 - Number of Iterations Examined Over Integral
sum	Real	Summary Results from Function F2
xi	Real	Integration Step Location

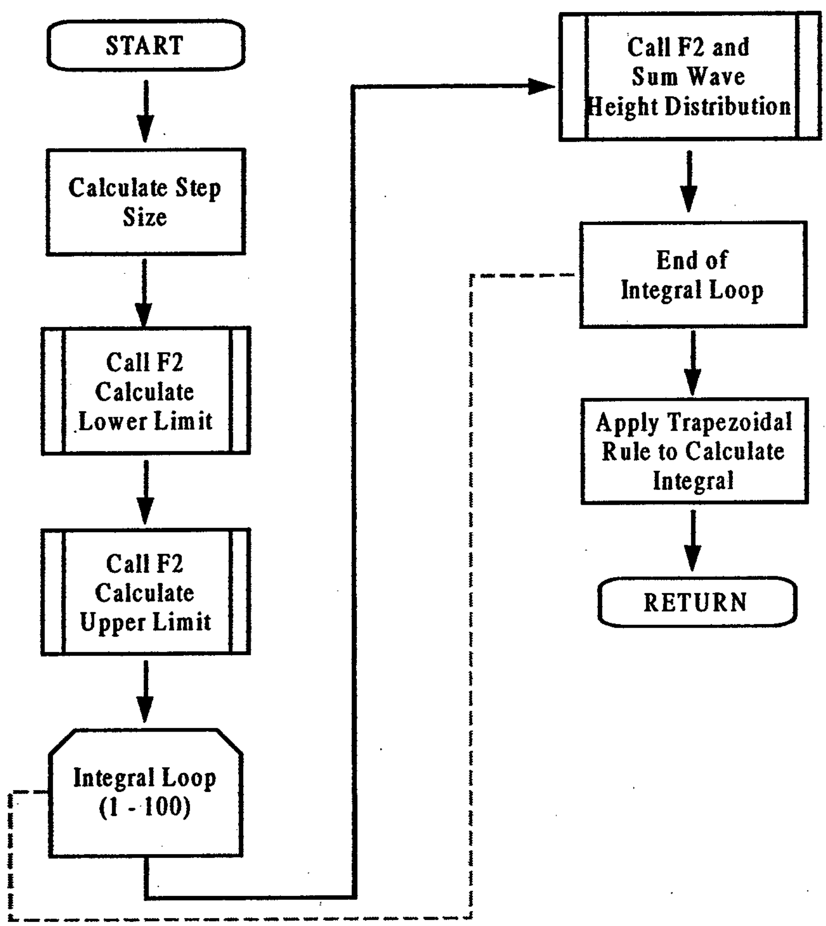
Functions Called from INTEGRAT ( ):

F2

INTEGRAT ( ) Called from Subroutines:

CALC_HB3
PERCENT

Figure 67. Function INTEGRAT Flowchart



5.67 Include File: COMMON.INC

Summary:

The include file COMMON.INC contains all the parameters set for the SURF Model.g

Defined Parameters:

dcal	Real	0.3048 - Feet to Meters Conversion
degrad	Real	PI / 180.0 - Conversion from Degrees to Radians
dirNum	Integer	180 - Array Dimension Used for Direction Arrays
freqNum	Integer	50 - Array Dimension Used for Frequency Arrays
g	Real	9.8
gamma	Real	0.42 - Empirical Wave Height Factor
iunit	Integer	Output File Unit
pi	Real	3.14159265
points	Integer	500 - Array Dimension Used for all Input Depth Arrays
raddeg	Real	180.0 / pi - Conversion from Radians to Degrees
rho	Integer	1030 - Water Density
rhoair	Real	1.2 - Air Density
sigma	Real	sigma_deg * degrad
sigma-deg	Real	5.0 - Angle in Degrees between Wave and Roller in the Thornton/Lippman Model (1996)
tpi	Real	2 * 3.14159265
zone_pct	Real	10% Surf Zone Width Percent of Breaking Waves

ACKNOWLEDGEMENTS

Mr. John Murdock from Naval Oceanographic Office provided many useful suggestions to surf model developments. The MSI errors were discovered by Dr. Nathaniel Plant, Marine Geosciences Division, Naval Research Laboratory. The input wave angle improvement was prompted by questions from Dr. Daniel Conley, SACLANT Undersea Research Center, La Spezia, Italy. Mr. David McNeal, Ms. Angela Richardson, and Ms. Lauriane Winsett from Neptune Sciences, Inc. performed compiler checks and revised of the flowcharts. SURF 3.2 was funded under PE 63207N and sponsored by the Space and Naval Warfare Systems Command (SPAWAR). The program manager is Mr. Tom Piwowar.

APPENDICES

Appendix A. INPUT AND OUTPUT DATA FORMATS

1. Input File Formats and model options

This section gives the formats for the files read or produced by SURF.

1.1 SURF Input File

The SURF input file contains 12 lines. Some of the lines may be blank; some are required. The format for each line of the input file is al follows:

Line	Description	Type	Units	Range
1	Input File Name	Char*40	-----	-----

The entry in line 1 must be the exact name of the input file. The first character of the file name must be in column 1. The file name is limited to 40 characters.

Line	Description	Type	Units	Range
2	Date and Time YYYYMMDDHH	Char*10	-----	-----

Line 2 is date-time information in the form YYYYMMDDHH. SURF simply reads this line and prints it out in the output file.

Line	Description	Type	Units	Range
3	Landing Zone Name	Char*40	-----	-----

Line 3 is a description of the beach. The string in line 3 cannot be longer than 40 characters or the string will be truncated. This line can be blank, but no information to identify the beach will appear in the output file.

Line	Description	Type	Units	Range
4	Input Depth Profile File Name	Char*40	-----	-----

Line 4 is the name of the input depth profile. The depth profile file name is limited to 40 characters.

Line	Description	Type	Units	Range
5	Sediment Type	Integer	-----	1-10

An entry in line 5 must be given if no depth profile file is included in line 4. If a depth profile is specified in line 4, this line should be left as blank. Allowable entries for bottom composition are as follows

```
1 = Boulders
2 = Cobble
3 = Pebbles
4 = Granules
5 = Very Coarse Sand
6 = Coarse Sand
7 = Medium Sand
```

8 = Fine Sand
9 = Very Fine Sand
10 = Silt

Line	Description	Type	Units	Range
6	Compass Heading Towards Beach	Real	Degrees	0-359

The compass heading toward the beach is the direction from sea to beach, perpendicular to the beach. Some examples of beach orientation are shown in Fig. 1, part (a).

Line	Description	Type	Units	Range
7	Wave Input Depth	Real	Feet	> 0

Line 7 is the depth in feet at the location of the input waves. The input waves can be in two formats:

(1) a directional wave spectrum from a file given in line 8. Straight coast refraction will be applied if the depth is deeper than available depth profile. If line 9 (wave refraction file) is not blank, this depth corresponds to the output depth where transformation coefficients are applied to offshore input wave. Further illustration is included in the section 1.5.

(2) sea and swell parameters in line 10, which are used to generate a synthetic directional wave spectrum within SURF;

Line	Description	Type	Units	Range
8	Input Wave Spectrum File Name	Char*40	-----	-----

Line 8 is the name of the optional input directional wave spectrum file. If a file is entered here then any wave input information line 10 is ignored during SURF execution.

Line	Description	Type	Units	Range
9	Input Wave Refraction File Name	Char*40	-----	-----

Line 9 is the name of the input refraction and shoaling file. It should be noted that the depth at the offshore boundary of the wave refraction computation domain should be the same as offshore wave spectrum input depth. A wave spectrum from line 8 or wave input from line 10 will be modified by the refraction angles and shoaling coefficients in this file. If this line is blank, then simple refraction and shoaling based on a straight coast assumption, i.e. parallel bottom contours, will be applied.

Line	Description	Type	Units	Range
10	Sea Wave Height	Real	Feet	> 0
	Sea Wave Period	Real	Seconds	1 - 30
	Sea Wave Direction	Real	Degrees	0 - 359
	Swell Wave Height	Real	Feet	> 0
	Swell Wave Period	Real	Seconds	1 - 30
	Swell Wave Direction	Real	Degrees	0 - 359

Wave direction is the direction from which waves come in degrees from North. Some examples of wave direction are shown in Fig. 1, part (b). If no directional wave spectrum file is given in line 8 then the model will produce a directional wave spectrum based on the sea and swell parameters given in this line. If a refraction-shoaling file is included then the internally generated spectrum will be refracted and shoaled to the depth in line 7.

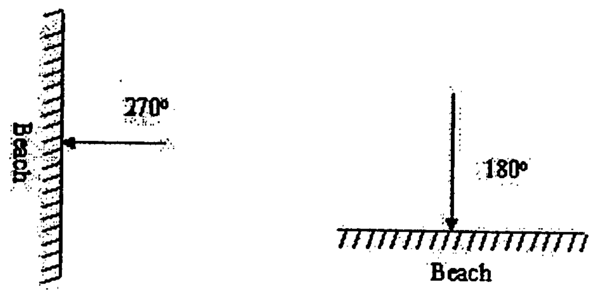
Line	Description	Type	Units	Range
11	Wind Speed	Real	Knots	> 0
	Wind Direction	Real	Degrees	0 - 359

	Tide Elevation	Real	Feet	+ or -

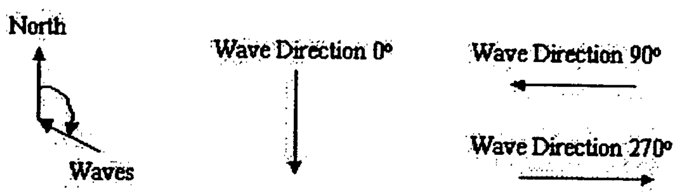
Line 11 gives wind and tide information. Wind direction is the direction from which wind comes in degrees from North.

Line	Description	Type	Units	Range
12	Output Grid Spacing	Real	Feet	see note

An entry must be made in line 12. If line 12 is negative then a short output will be produced. Note: the range of intervals is limited by array sizes and by the surf zone width computed by the model. Error messages will warn the user if the intervals are too small, say less than 2 ft, or too large.



(a) Beach Orientation Definition. Arrows show sight lines from deep water toward the beaches.



(b) Wave Direction Definition. Directions are those from which waves come in degrees relative to North.

Fig. 1 Beach orientation and wave direction definitions.

1.2 Depth File

Line	Description	Type	Range
1	Title	Char*80	-----

Line 1 is a simple alphanumeric identifier. The information in this line is not used in SURF.

Line	Description	Type	Range
2	Units for Distance Offshore	Integer	1,2 or 3

Line 2 identifies the units of offshore distances associated with the entries in line 4 and after.

1 - Distances in Feet
2 - Distances in Meters
3 - Distances in Yards

Line	Description	Type	Range
3	Units for Depth	Integer	1,2 or 3

Line 3 identifies the units of the depths associated with the entries in line 4 and after.

1 - Depths in Feet
2 - Depths in Meters
3 - Depths in Fathoms

Line	Description	Type	Range
4+	Index number	Integer	1 - 500
	Distance offshore	Real	----
	Depth positive down	Real	----

The depth profile is contained in lines 4 and after. The distance coordinate is zero at the water's edge and increases offshore. The depths associated with each distance are positive down. See Appendix B for a sample input depth profile file.

1.3 Directional Wave Spectrum File

The input directional wave spectrum file contains nine preliminary lines of information followed by blocks of data, where each block is associated with a frequency band. The elements of each block are values of spectral energy density in units of meters-squared per hertz per radian.

Lines 1-3 identify the time and location of the spectrum. This information is not used by the model in calculating wave or surf parameters.

Line	Description	Type	Units	Range
1	Longitude	Real	Degrees	-180 - 180
2	Latitude	Real	Degrees	-90 - 90
3	Date - (YYYYMMDD)	Real	-----	----

Line	Description	Type	Units	Range
4	Number of Angles	Integer	-----	1 - 180

Line 4 gives the number of direction bins in the directional wave spectrum. The number in line 4 must equal the number of rows times the number of columns in line 5.

Line	Description	Type	Units	Range
5	Number of Rows	Integer	-----	+ number
	Number of Columns	Integer	-----	+ number

This line gives information for reading each block of spectral energy densities. Each block has the same number of elements, which is the number of rows times the number of columns. Note that the number of elements must be an even number. If the input directional wave spectrum has 24 direction bins then acceptable pairs of row-column combinations are : 24 1; 12 2; 6 4; 3 8; 8 3; 4 6; 2 12; 1 24.

Line	Description	Type	Units	Range
6	Number Frequency Bands	Integer	-----	1 - 50

Line 6 contains the number of frequency bins in the directional wave spectrum.

Line	Description	Type	Units	Range
7	Initial Direction	Real	Degrees	0 - 359

The directional bands associated with the spectrum must increase monotonically. Line 7 gives the initial direction, which will be the smallest angular value in degrees, positive clockwise from North.

Line	Description	Type	Units	Range
8	Width of Direction Bin	Real	Degrees	2 - 180

The number of directional bands is given in line 8.

Note: the width of the direction bins in degrees times the number of direction bins must equal 360 degrees.

Line	Description	Type	Units	Range
9	Direction of Waves	Integer	-----	1 or 2
	1 - Direction waves are coming from			
	2 - Direction waves are going to			

Following the initial nine lines, are blocks of values of spectral energy density in units of meters-squared per hertz per radian. The first line of each block will contain the lower, center and upper frequency of the frequency band associated with that block. The block of values is a rectangular matrix of values in order from left to right being from left to right in direction in increments of the directional bandwidth given in line 8. The block of data must represent directions covering 360 degrees from the initial directional clockwise. In general, the format of each block is a follows:

Directional Wave Spectrum - Blocks are repeated for each Frequency Bin

Line	Description	Type	Units	Range
10	Bin Number	Integer	-----	1 - 50
	Lower Limit of Frequency Bin	Real	hertz	> = 0
	Center of Frequency Bin	Real	hertz	> = 0
	Upper Limit of Frequency Bin	Real	hertz	> = 0
11+	Directional Wave Spectrum	Real	m^2/Hz/rad	> = 0

The elements of each block of values comprising the spectral energy densities for a given frequency are in the form of a rectangular matrix of numbers of the number of rows times the number of columns, as in line 5.

1.4 Input Wave Refraction and Shoaling Input File

Using the input wave refraction and shoaling input file is an advanced procedure. The refraction and shoaling files used to modify an input directional wave spectrum to a spectrum representative of conditions at the depth given in line 7 of the SURF input file.

Line	Description	Type	Units	Range
1	Header	Character	-----	-----
2	Header	Character	-----	-----
3	Input and Output Depths	Real	Feet	-----

Lines 1-3 are strings of identifying text. The information is not used in computation. In line 3, input depth is the offshore boundary depth, and output depth corresponds to the depth where the transformation coefficients are saved, i.e. the spedepth of line 7 of surf input file.

Line	Description	Type	Units	Range
4	Number of Angles	Integer	-----	1 - 180
5	Number of Rows	Integer	-----	+ number
	Number of Columns	Integer	-----	+ number
6	Number of Freq. Bins	Integer	-----	1 - 50
7	Initial Direction	Real	Degrees	0 - 359
8	Width of Direction Bin	Real	Degrees	2 - 180
9	Direction of Waves 1 - Direction waves are coming from 2 - Direction waves are going to	Integer	-----	1 or 2

Lines 4-9 are similar to those in the input directional wave spectrum file.

Refraction Angles - This section is repeated for each frequency

Line	Description	Type	Units	Range
10	Bin Number	Integer	-----	1 - 50
	Lower Limit of Frequency Bin	Real	Hertz	> = 0
	Center of Frequency Bin	Real	Hertz	> = 0
	Upper Limit of Frequency Bin	Real	Hertz	> = 0
11+	Refraction Angles	Real	Degrees	0 - 359

End of Refraction Angles

The elements of each block of values comprising the refraction angles for a given frequency are in the form of a rectangular matrix with the number of rows and columns in line 5. Pad fields with zeros, if necessary.

Line	Description	Type	Units	Range
Line A+1	Header 1 for Shoaling Coefficients	Char*80	-----	-----
Line A+2	Header 2 for Shoaling Coefficients	Char*80	-----	-----
Line A+3	Header 3 for Shoaling Coefficients	Char*80	-----	-----

The `Line A+` numbering above and below denotes information after the block of refraction angles.

Shoaling Coefficients - This section is repeated for each frequency

Line	Description	Type	Units	Range
Line A+4	Bin Number	Integer	-----	1 - 50
	Lower Limit of Freq Bin	Real	Hertz	> = 0
	Center of Freq Bin	Real	Hertz	> = 0
	Upper Limit of Freq Bin	Real	Hertz	> = 0

```
Line A+5+   Shoaling Coefficients   Real        m²/m²        -------
End of Shoaling Coefficients
```

The elements of each block of values comprising the shoaling coefficients for a given frequency are in the form of a rectangular matrix of values with the number of rows and columns given in line 5. Pad fields with zeros, if necessary.

Note: The angles and coefficients in this file must be defined over the entire range (0, 360) degrees. A partial sector definition (e.g. 0 to 180 degrees) will cause errors. If the input data are not available over the entire range pad the refraction and direction bins with zeros.

1.5 Model Options

This section gives options in SURF that control wave refraction, equilibrium profile option, and the output files.

Wave Refraction Options

In general, the depth profile should cover depths to around 30 ft. If the depth of input waves is deeper than the deepest depth in the profile, i.e. outside of the profile-covered area, two options are available to consider wave refraction to bring the input waves to the edge of the area over which SURF is to operate. If no bathymetry information is available, straight coast refraction, assuming parallel bottom contours, will be used. If bathymetry information available, one can use the wave modeling option where transformation coefficients for refraction and shoaling are computed. This option is generally only used when the bathymetry is complicated.

As illustrated in Fig. 2, straight coast refraction brings the wave input to the edge of the profile-covered area starting point. It should be noted that if spedepth is inside the profile-covered area, then it becomes starting point. Then no additional wave refraction will be applied. The first output point corresponds to a location where the percent of wave breaking has reached 5%. This avoids a long listing of surf output over long stretches of flat, gently sloping bottoms.

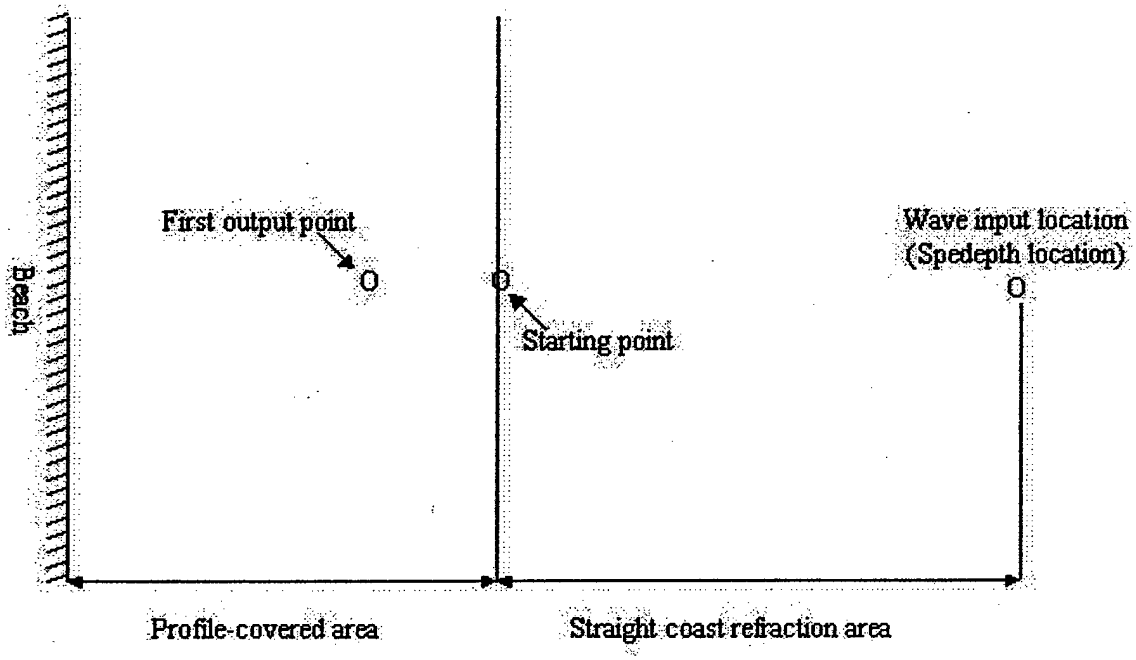


Fig. 2 Illustration of straight coast refraction option. Straight coast refraction brings wave input to the edge of the profile-covered area, i.e. the starting point.

For the wave modeling option, wave models such as REFDIF, STWAVE and SWAN pre-compute needed transformation coefficients for a given bathymetry. Input line 9 specifies the wave refraction file. As illustrated in Fig. 3, the spedepth (input line 7) corresponds to the output depth of the refraction computation. For accuracy, it is requires that the output depth is within the profile-covered area. This is because no additional straight coast refraction will be applied if it falls outside of the profile-covered area. The output depth should not be too shallow (e.g. within the surf zone), because the transformation coefficient approach assumes that no depth induced wave breaking has occurred at the output point. It is recommended that the output depth should be around 25 to 30 ft or deeper depending on the bathymetry and wave conditions. The offshore wave input location needs to be at the same depth as the offshore boundary of the refraction file computation.

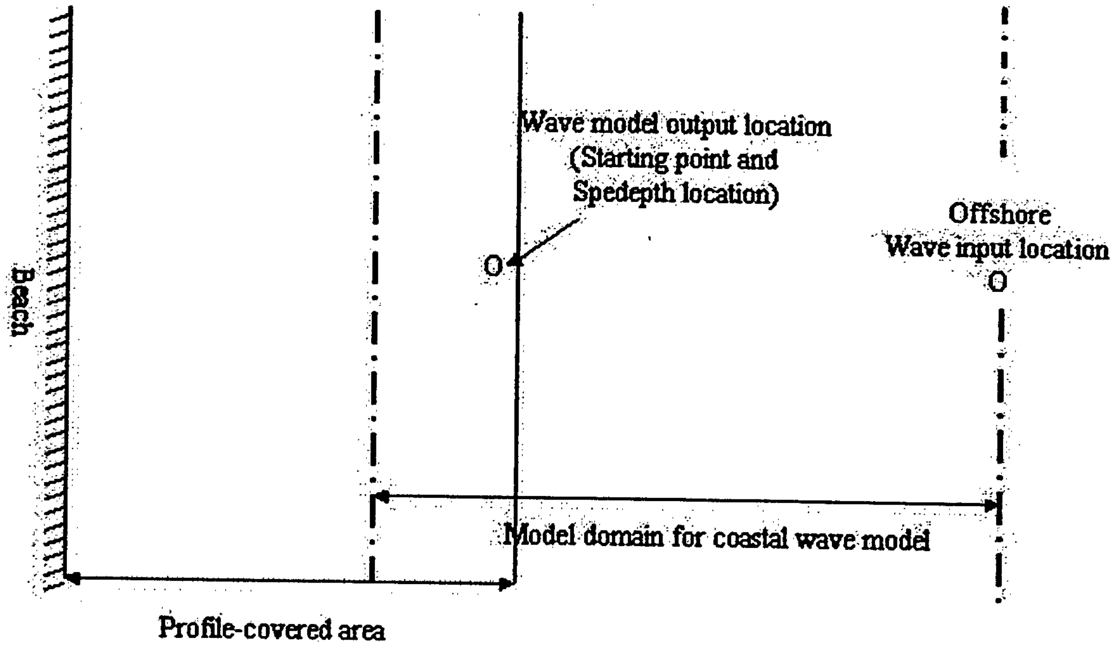


Fig. 3 Illustration of wave modeling option.

Equilibrium Profile Option

The equilibrium profile, based on sediment size, is used if a depth profile is not available. In the code, its maximum depth, also the starting depth, is set to 10 m, except for the wave refraction file option in which the maximum depth corresponds to spedepth.

Wave Spectrum Output Option

To obtain an output directional wave spectrum file, place the character "+" in front of the directional wave spectrum file name in line 9 of the basic input file. The output file will give the directional wave spectrum associated with the output point, i.e. the spedepth depth. The output spectrum file will have the same file name as the input file name but with the extension `.dws`.

Short Output

In SURF, the user can control the amount of data in the output file. If line 12 contains a zero or a negative number, a short output, without cross shore profiles of surf parameters, will be produced. The short output is similar in format to naval surf observations.

2. Output File Formats

2.1 Basic Output File

The SURF detailed output has three output sections delineated by lines of asterisks. The first section contains input parameters describing the directional wave spectrum. The second section is the coded surf forecast with variables specific to military surf observations. The final section is the optional detailed surf output, which is comprised of a table of cross shore surf zone parameter. These parameters include cross shore distance, depth, wave height, wave breaking, wave angle and longshore current. The filename generated has the same name as the input file but the extension is `.out`.

Section 1

Line	Description	Type	Units
Line 1	Surf Forecast Header	Character	-----
Line 2	Blank Line	------	-----
Line 3	SURF Model Version	Character	-----
Line 4	Date and Time of Forecast	Character	-----
Line 5	Output File Name Information	Character	-----
Line 6	Landing Zone Name	Character	-----
Line 7	Sight Line Toward Beach	Real	Degrees
Line 8	Depth Profile Name or Beach Sediment Type	Character	-----
Line 9	Wave Input Depth	Real	Feet
Line 10	Spectrum Usage Text	Character	-----
	or		
	Sea Wave Height	Real	Feet
	Sea Period	Real	Seconds
	Sea Direction	Real	Degrees
Line 11	Spectrum File Name	Character	-----
	or		
	Swell Wave Height	Real	Feet
	Swell Period	Real	Seconds
	Swell Direction	Real	Degrees
Line 12	Wind Speed	Real	Knots
Line 13	Wind Direction	Real	Degrees
Line 14	Tide Level	Real	Feet
Line 15	Blank Line	Character	-----
Line 16	Wave Refraction Option	Character	-----
Line 17	Starting Depth	Real	Feet
Line 18	Output Interval	Real	Feet
Line 19	Computational grid Spacing	Real	Feet
Line 20	Input Spectrum Type	Character	-----
Line 21	Significant Wave Height Offshore	Real	Feet
Line 22	Wave Peak Period	Real	Seconds
line 23	Average Wave Direction	Real	Degrees
line 24	Percent Breaking Waves at Starting Depth	Real	Percent

It should be noted that starting depth on line 17 is the depth after offshore waves have brought to the edge of the profile-covered area through either straight coast refraction or refraction file computation. This depth depends on the depth profile, tide and wave input (spedepth) location.

Section 2

Line	Description	Type	Units

Line	1	Code Surf Forecast	Character	-----
Line	2	Significant Breaker Height	Real	Feet
Line	3	Maximum Breaker Height	Real	Feet
Line	4	Dominant Breaker Period	Real	Seconds
Line	5	Dominant Breaker Type	Character	-----
Line	6	Breaker Percentages	Character	Percent
Line	7	Breaker Angle	Real	Degrees
Line	8	Littoral Current	Real	Knots
Line	9	Number of Surf Lines	Real	-----
Line	10	Surf Zone Width	Real	Feet
Line	11	Wind Speed	Real	Knots
Line	12	Average wave length	Real	Feet
Line	13	Wind Direction	Real	Degrees
Line	14	Blank Line	Character	-----
Line	15	Modified Surf Index	Real	-----

Section 3

Line		Description	Type	Units
Line	1	Blank Line	-----	-----
Line	2	Heading - Detailed Surf Output	Character	-----
Line	3	Blank Line	Character	-----
Line	4	Text Heading Line	Character	-----
Line	5	Text Heading Line	Character	-----
Line	6	Text Heading Line - Units	Character	-----
Line	7	Blank Line	Character	-----
Line	8-EOF	Index Number	Integer	-----
		Distance Offshore	Real	Feet
		Water Depth	Real	Feet
		Significant Breaker Height	Real	Feet
		Maximum Breaker Height	Real	Feet
		Percent Breaking Waves	Real	Percent
		Breaker Angle	Real	Degrees
		Littoral Current	Real	Knots

The first output point in line 8 in section 3 corresponds to a point where percent of wave breaking has reached 5%.

2.2 Data Only Output File

The data only output file contains the same information in the same format as the section 3 of the detailed model output, except the file does not contain header information. It is useful in graphic applications.

2.3 Shallow Water Directional Wave Spectrum

The shallow water directional wave spectrum output file is created when the first character of line 6 in the basic input file is a "+". This file has the same file name as the input file except that the file extension will be .dws. The first row contains the center frequencies of the directional wave energy spectrum. The first column defines the wave directions of the directional wave energy spectrum. The remaining matrix elements comprise the directional wave energy spectrum.

	Description	Type	Units	Range
Row 1	Frequency Bins	Real	hertz	0 - 0.5
Column 1	Wave Direction	Real	degrees	0 - 359
Other elements	Spectral Energy Density	Real	m^2/(Hz-rad)	0 - 999

Appendix B. Error Message Descriptions

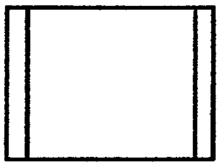
Error Message	Subroutine Generating Error	Suggested Solution to Resolve Error
Error 115 - Opening Directional Wave Spectrum File.	`readspec`	Check wave spectrum file name in the input file- line 5. Verify the location of the spectrum file is the same as the input file.
Error 120 - Opening input file.	`srfsetup`	Check the name of the input file typed at the command prompt (`surf32 <fn.in`) or the name typed during execution (Enter `fn.in`).
Error 125 - Opening of Input Depth File.	`c_in_dep`	Check depth profile file name in the input file - line 4. Verify the location of the depth file is the same as the input file.
Error 130 - Opening Refraction File.	`readrfrc`	Check refraction file name in the input file - line 6. Verify the location of the refraction file is the same as the input file.
Error 145 - Input depth profile has more data points than allowed. Check depth profile. Program stopped.	`c_in_dep`	The maximum number of depth points allowed is 500. Modify depth input file to contain only 500 depth values.
Error 165 - No sediment type selected for Equilibrium Profile.	`equilprf`	A Slope/Sediment Type was not set correctly in the input file line 8. The value must be inclusive of 1-10
Error 170 - No Surf.	`surf`	Check the heading toward the beach in the input file, line 7 and the spectrum input file. There may be no surf in the area.

Error 180 - Problem gridding to output file. Program stops.	`prt_out1` `prt_out2`	Check that the input depth profile extends to the beach shoreline and that the tide level - line 12 is not too high.
Error 185 - Problem with wave height values.	`new_brk`	Check the input depth profile. The data may need to be smoothed due to unusual slopes. (Hint: too many negative slopes.)
Error 195 - Significant wave height outside surf zone less than 0.5 ft - no further calculations.	`s_nosurf`	Check the heading toward the beach in the input file - line 7.
Error 200 - Surf forecasts are for situations when waves are more important than winds. This is not the case for input waves and winds. Forecasts may not be valid.	`s_coeff`	Check the input wave and wind conditions in the input file - line 11 and line 12.
Error 205 - Water edge not found. Check tide and/or depths. Program stopped.	`s_tide`	The input depth profile must extend to the beach including the addition of a tide, if specified. There must be a depth at either 0.0, an onshore value, or an elevation.
Error 210 - Wave direction not toward the beach - no further calculations.	`rad_st2`	Check the heading toward the beach in the input file, line 7 and/or the directional wave spectrum file.
Error 215 - Wave induced set-up not converging to tolerance.	`setup`	The input depth profile must be smoothed.
Error 220 - Wave induced Set-up is not converging. Ending program.	`main_wav`	The input depth profile must be smoothed.

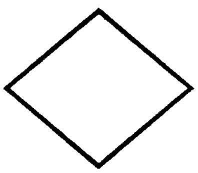
Appendix C. Flowchart Symbol Index

Terminus (Start, Return, End)

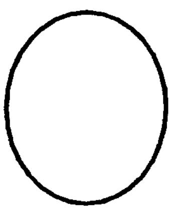
Process or Calculation



Call to Subroutine or Function

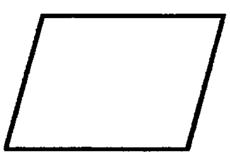


Decision

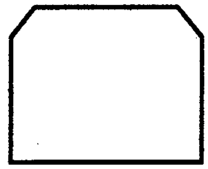


Connector

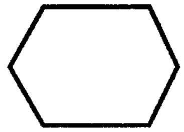
Keyboard Input



Input or Output

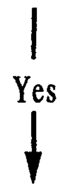


Loop Limitation

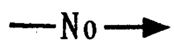


Preparation Prior to a Process or Initialization of Variables

Symbol Connector



Yes Connector



No Connector

Appendix D. Acronyms

CNMOC	Commander, Naval Meteorology and Oceanography Command
CSCI	Computer Software Configuration Item
CSU	Computer Software Unit
DWS	Directional Wave Spectrum
EOF	End of File
Hz	Hertz
LHS	Left Hand Side of Energy Balance Equation
m	Meter
N	Newton
MSI	Modified Surf Index
NRL	Naval Research Laboratory
OAML	Oceanographic and Atmospheric Master Library
ONR	Office of Naval Research
RHS	Right Hand Side of Energy Balance Equation
RSM	Refraction/Shoaling Matrix
SPAWAR	Space and Naval Warfare Systems Command